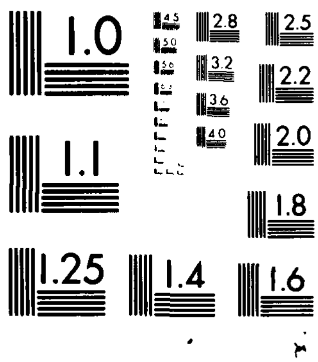
AD-A099 724 COAST GUARD RESEARCH AND DEVELOPMENT CENTER GROTON CT F/G 13/10
ICEBREAKING AND OPEN WATER TESTS PERFORMED ON THE USCG CUTTER K--ETC(U)
MAY 80 M J GOODWIN
UNCLASSIFIED CGR/DC-6/80 USCG-D-24-81 NL

1 of 1

END
DATE FILMED
6-81
DTIC



MICROCOPY RESOLUTION TEST CHART

AD A099724

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
USCG-D-24-81	AD-A099724	

4. Title and Subtitle	5. Report Date
ICEBREAKING AND OPEN WATER TESTS PERFORMED ON THE USCG CUTTER KATMAI BAY (WTGB-101)	MAY 1980
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
Michael J. GOODWIN	CGR&DC-6/80

9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
United States Coast Guard Research and Development Center Avery Point Groton, Connecticut 06340	11. Contract or Grant No.

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Department of Transportation United States Coast Guard Office of Research and Development Washington, D.C. 20393	FINAL REPORT
	14. Sponsoring Agency Code

15. Supplementary Notes

12 59

16. Abstract

The results of icebreaking trials performed on the icebreaking tug, USCGC KATMAI BAY (WTGB-101), are presented. These trials were conducted in Whitefish Bay and the St. Mary's River near Sault Ste. Marie, Michigan, during January - March 1980. Trials were conducted in all modes of icebreaking. Bollard pull tests and limited maneuvering tests in ice were also conducted. Open water trials performed in July 1979 in Whitefish Bay are also reported. These included speed and maneuvering (tactical data) trials. Spiral tests were also performed to determine directional stability.

17. Key Words	18. Distribution Statement
Icebreaking Ship Testing Great Lakes Ice Conditions Ship Performance	Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED		

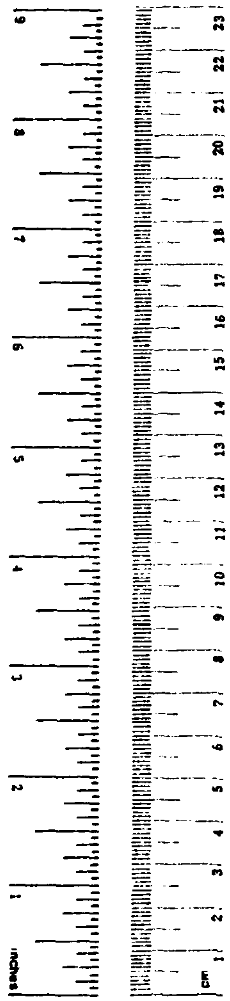
408730

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

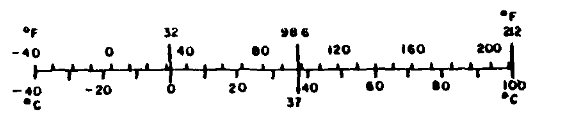
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This report resulted from the joint effort of personnel from the U.S. Coast Guard Naval Engineering Division, David W. Taylor Naval Ship Research and Development Center (DTNSRDC), Carderock Laboratory, Bethesda, Maryland; the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire; and the U.S. Coast Guard Research and Development Center (R&DC), Groton, Connecticut. Test reports prepared by DTNSRDC and CRREL supplement this report.

TABLE OF CONTENTS

1.0 INTRODUCTION

Icebreaking trials were conducted on the 140' icebreaking tug, USCGC KATMAI BAY (WTGB-101), during January, February, and March 1979. During July 1979 tactical data trials were conducted on the same cutter. This report documents the results of these trials.

The USCGC KATMAI BAY is the first ship of a class of tugboats designed with enhanced icebreaking capability. These cutters will replace 110' WYTMs on the Great Lakes. The primary duties during winter months for the 140' WTGBs will be keeping shipping lanes open and assisting vessels transiting ice-clogged channels.

The principal characteristics of the 140' WTGB are listed below:

LOA	140'0" (42.67 m)
LBP	130'0" (39.62 m)
BEAM	37'6" (11.43 m)
DRAFT(MAX)	12'0" (3.66 m)
FULL LOAD DISPLACEMENT	662 TONS
SHAFT HORSEPOWER	2,500 SHP
SPEED, OPEN WATER	14.7 KNOTS

The 140' WTGB is equipped with a diesel electric, DC/DC, propulsion system. Two diesel generator sets are installed driving a single shaft. Of special note is the fact that an air bubbler system is installed to provide hull lubrication. This installation is the first of its type on a U.S. vessel.

The USCGC KATMAI BAY was tested to confirm design predictions. These tests included icebreaking performance for level icebreaking, brash icebreaking, and ramming as well as tactical data trials in open water and limited maneuvering trials in ice. Seakeeping trials were conducted in September 1979 on the USCGC MOBILE BAY (WTGB-103). The results of the seakeeping trails will be reported separately.

The Coast Guard Research and Development Center (R&DC), the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), and the David W. Taylor Naval Ship Research and Development Center (DTNSRDC) were asked by Commandant (G-E) in a letter dated 24 April 1978 if they would be willing to participate in the test program and to what extent. All three responded that they did wish to participate. As a result, a joint effort was conducted with R&DC managing the test program, CRREL performing the ice measurements, and DTNSRDC performing structural and machinery measurements.

The objectives of the test program were:

a. To define the capability of the cutter in various icebreaking modes,

b. To determine the benefit from using the bubbler system,

c. To verify that the machinery is adequate for icebreaking,

d. To provide data to verify calculation procedures,

e. To determine the operational characteristics of the cutter and provide tactical data to the operators, and

f. To obtain new data not collected before for use in future design calculations.

In order to accomplish these objectives, periods for testing the cutter were set aside during January, February, March, and July 1979. Ice testing was conducted from 29 January to 13 February and from 13 to 17 March. Tactical data trials were conducted on 9 and 10 July 1979.

The ice trials took place in Whitefish Bay, Lake Superior, and the St. Mary's River near the cutter's homeport of Sault Ste. Marie, Michigan. Nearly all level icebreaking and ramming trials were conducted in Whitefish Bay. Brash icebreaking trials were conducted primarily in the St. Mary's River but some trials were performed in the shipping channel in Whitefish Bay. Shaft vibration and rudder torque tests took place at the lower end of the St. Mary's River where it enters Lake Huron. Tactical data trials were performed in Whitefish Bay.

The icebreaking trials encompassed level icebreaking, the effect of the air bubbler system on level icebreaking, brash icebreaking, the effect of the bubbler system on brash icebreaking, and ramming in level ice and ice ridges. A bollard pull test was also performed during the winter test period. Shaft vibrations in open water and rudder torque in turns were measured along with turning circle data in level and brash ice. A comparison test was conducted with the 140' WTGB running alongside a 110' WYTM. The USCGC ARUNDEL (WYTM-90) participated in this test.

Coast Guard Air Station Traverse City assisted in the test program by providing HH-52 helicopters and air crews. These helicopters were used for aerial photography and for ice thickness measurments using an impulse radar provided by CRREL. This radar was still experimental and was checked by ground measurements. Comparison results for the two methods are presented in reference (2).

Base Sault Ste. Marie provided much assistance in preparing test instruments and repairing test vehicles. During the tests the ship returned to Base Sault Ste. Marie every night except one. This was required because of lack of accommodations on the cutter since the test party doubled the size of the ship's crew of 17 men.

Testing days during the winter test period were generally clear and cold with temperatures ranging from -15^{o}F to +35^{o}F (-27^{o}C to 2^{o}C). Weather conditions had little or no adverse effect on the test results.

Concurrent operations caused some delays but all tests were completed in the time frame originally scheduled. These concurrent operations introduced the test party to actual winter operations in the area. The KATMAI BAY assisted ore carriers beset in the ice on several occasions and also helped to flush ice from ferry crossings.

Tactical data trials in deep water took place on 9 and 10 July 1979. Information collected included data on turns at various speeds and rudder angles, speed versus shaft RPM, and stopping and reversing distances. Dieudonne spiral maneuvers were performed during this period to check the directional stability of the vessel. Weather conditions for these tests were very favorable with winds under 8 knots for all the tests.

2.0 TESTING AND INSTRUMENTATION

2.1 General

The following tests were conducted:

1. Continuous level icebreaking with and without the air bubbler system activated,
2. Brash icebreaking with and without the air bubbler system activated,
3. Bollard pull,
4. Icebreaking by ramming with and without the air bubbler system activated,
5. Comparison with 110' WYTM,
6. Maneuvering in level ice,
7. Maneuvering in brash ice,
8. Shaft/propeller vibration validation,
9. Open water rudder torque validation,
10. Directional stability validation,
11. Shaft RPM versus speed in open water,
12. Stopping distance and time,
13. Turning circle dimensions, and
14. Quick reversals.

Seakeeping trials were conducted with the USCGC MOBILE BAY (WTGB-103) during September 1979 off the Virginia Capes and will be reported separately.

A list of test runs is given in Tables A-1 through A-10 of Appendix A. Included in these tables are some of the test parameters for reference. Values given in these tables are only approximations and should be used with caution.

This report, together with references (1) through (6), comprise all the reports on the icebreaking and tactical data trials performed on the KATMAI BAY.

2.2 Instrumentation

Instrumentation used by DTNSRDC and CRREL personnel is detailed in the reports by these agencies. The R&DC was responsible for collecting data on ship motions. The instrumentation used consisted of a gyro stabilized platform for pitch, roll, and yaw measurements and a stable platform for measuring surge, sway, and heave accelerations. Data was recorded in analog form by a 14-channel magnetic tape recorder. Also recorded was the common time code provided by DTNSRDC.

A doppler radar which had been calibrated for low speeds was used to determine ship speeds for some tests. The radar was effective and accurate so long as the ice surface roughness was sufficient to return a strong signal.

Installed instruments on the ship were used to collect weather data and water temperatures. Vessel position was also determined by the ship's crew.

2.3 Supplemental Reports

These reports are references (1) through (6). The content of each of these reports is generally as follows:

Reference (1) - Analysis of the Performance of a 140-Foot Great Lakes Icebreaker: USCGC KATMAI BAY. CRREL Report 80-8 by George P. Vance, February 1980.

> This report details the icebreaking capabilities of the ship. Plots of speed versus shaft horsepower are shown for the various ice conditions tested. Bubbler system effectiveness is also examined. Acceleration performance in open water is given together with a penetration index for ramming.

Reference (2) - Characteristics of Ice in Whitefish Bay and St. Mary's River During January, February, and March 1979. CRREL Special Report 175 by George P. Vance, May 1980.

> Ice and weather conditions encountered are given in this report. A daily summary of ice tests is given. Ice thickness and temperature profiles are given for the test reaches. Snow cover thickness is included. Mechanical properties of the ice are discussed as are density and salinity measurements. Ice friction tests are detailed also. A weather summary is included as an appendix to this report.

Reference (3) - Machinery and Ship Tracking Data for Icebreaking Trials Conducted on U.S. Coast Guard Cutter KATMAI BAY (WTGB-101). DTNSRDC Report 80/024 by Donald H. Drazin, February 1980. NTIS No. AD-A082373.

> Most of the data collected is included in this report which covers machinery parameters plotted throughout selected test runs. Maneuvering in ice trials are covered by this report as are the rudder validation trials and bollard pull tests.

Reference (4) - Hull Strains and Load Estimates on the Coast Guard 140-Foot Icebreaking Tug KATMAI BAY During Great Lakes Icebreaking Operations. DTNSRDC Report by W. Hay, January 1980.

> Local hull strains measured in one span each of two frames in the forward ice belt are discussed in this report. The static calibration of the strain gauges is described in detail. Sample strain gauge records are given together with tables of maximum measured strains. Plots of strain versus ship speed for continuous plate icebreaking runs and strain versus pitch angle for icebreaking by ramming runs are included. A discussion of icebreaking loads is included.

Reference (5) - Propulsion System Vibrations Test and Evaluation Report, USCGC KATMAI BAY. DTNSRDC Report 80/030 by N.W. Huzil, March 1980. NTIS No. AD-A081599.

Reporting of shaft vibration measurements was accomplished in this report. Plots of alternating torque and thrust and thrust bearing housing vibrations are presented. Maximum vibrations are tabulated. Data is reported in compliance with Military Standard 167-2 requirements. Data for open water and for icebreaking are shown.

Reference (6) - KATMAI BAY (WTGB-101) Speed, Tactical, and Maneuvering Trials. DTNSRDC Report 79/106 by Robert R. Hunt and Lowry L. Hundley, November 1979. NTIS No. AD-A077587.

Tactical data in open water collected in July 1979 are detailed in this report. Data includes speed versus shaft RPM, tactical diameters for various speeds and rudder angles, and stopping and reversing distances and times.

Reference (7) - Power Predictions for the United States Coast Guard 140-Foot WYTM Represented by model 5336. DTNSRDC Report SPD-223-16 by E.E. West, April 1975.

3.0 DESCRIPTION OF TESTS AND RESULTS

3.1 Level Icebreaking

Objectives:

1. To determine the cutter's icebreaking capability in the continuous mode

2. To determine the ice loads on the bow framing

3. To determine the vibration characteristics of the shafting system in the continuous icebreaking mode

4. To determine the propulsion motor behavior in the continuous icebreaking mode

5. To determine the propulsion generator set behavior in the continuous icebreaking mode

Time and Scope of Test Runs:

A total of 16 test runs were made in level ice between 11 and 19 inches (28 to 48 cm) thick. These tests were conducted on 30 and 31 January and 9 February 1979. They are listed as runs numbered 1000 to 1331 in Table A-1 of Appendix A.

Data Collected:

The following ice data was collected:

1. Thickness (CRREL)
2. Temperature Profile (CRREL)
3. Salinity (CRREL)
4. Snow cover thickness (CRREL)
5. Hull friction (CRREL)
6. Density (CRREL)

In addition, the hull roughness, initial draft and trim of the ship, and the water depth were recorded. Data collected on board the KATMAI BAY is listed below. The type of data and the agency which collected the data is also shown in parentheses.

1. Shaft torque (CONT) (including torque variations) (DTNSRDC)
2. Shaft RPM (CONT) (DTNSRDC)
3. Thrust (CONT) (including thrust variations) (DTNSRDC)
4. Ship speed (DIGITAL) (DTNSRDC)
5. Motor volts (DIGITAL) (DTNSRDC)
6. Motor amps (DIGITAL) (DTNSRDC)
7. Motor exc. volts (DIGITAL) (DTNSRDC)
8. Motor exc. amps (DIGITAL) (DTNSRDC)
9. Motor temperature (DIGITAL) (DTNSRDC)

10. Time standard (keyed to all data channels) (DIGITAL and CONT) (DTNSRDC)
11. Generator RPM (DIGITAL X2) (DTNSRDC)
12. Generator volts (DIGITAL X2) (DTNSRDC)
13. Generator amps (DIGITAL X2) (DTNSRDC)
14. Generator exc. volts (DIGITAL X2) (DTNSRDC)
15. Generator exc. amps (DIGITAL X2) (DTNSRDC)
16. Starboard generator temperature (DIGITAL) (DTNSRDC)
17. Thrust bearing longitudinal, vertical, and transverse (horizontal) vibration frequency and amplitude (CONT X3) (DTNSRDC)
18. Trim angle (CONT) (R&DC)
19. Hull strains (CONT X8) (DTNSRDC)
20. Longitudinal acceleration (CONT) (R&DC)

CONT(INUOUS) = Analog Data
DIGITAL = Digital Data
MANUAL = Record On Data Form
X2 = 2 Channels of Data

Test Results:

The results of the ice measurements are given in reference (2). Hull friction measurements are detailed in reference (1) as are the overall performance results for the cutter. Machinery response for selected runs is shown in reference (3). Runs 1100, 1110, 1120, 1130, and 1320 were the test runs selected. Hull strain measurements are given in reference (4) and reference (5) includes limited vibrations measurements. Average pitch angle measurements are also presented in reference (4). Longitudinal acceleration measurements have not been presented because they were at an extremely low level.

Curves of speed versus shaft horsepower in level ice are shown in Figure 7 of reference (2) which has been repeated below. The speeds obtained with 2,500 SHP fall very close to the predicted speeds from the model tests performed for this class and the design predictions appear to be very close to the actual ship performance.

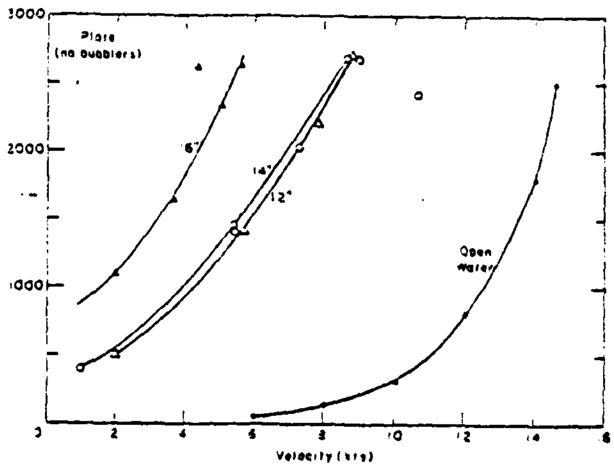


Figure 7 Shaft horsepower vs velocity for plate ice with no bubblers in operation (3 to 5 in of snow cover, h = 12 to 15 kpsi?)

Hull strains were not excessive during level ice runs. An estimate of the normal ice loading is given in reference (4). Installed machinery functioned properly during the trials and there were no unexpected findings as a result of the machinery measurements.

All of the objectives of this test were satisfied. Ice approximately 22-24 inches (56-61 cm) thick was required to determine the limiting icebreaking capability of the cutter. Ice of this thickness was not present in the test area.

3.2 Bubbler Effects in Level Ice

Objective:

To determine the effectiveness of the bubbler system in continuous plate icebreaking.

Time and Scope of Test Runs:

Four test runs were made on 31 January 1979 with the forward bubbler manifolds activated. These tests are numbered 2001 to 2030 in Table A-1.

Twelve runs were made with all of the air manifolds open. These tests took place on 31 January and 9 and 10 February 1979. Ice thicknesses between 11 and 26 inches (28-66 cm) were encountered. Run numbers 2100 to 2310 cover these tests.

Data Collected:

The data collected for these tests was the same as that collected in the level icebreaking tests with the following additions:

1. Bubbler engine RPM (MANUAL) (R&DC)
2. Bubbler compressor pressure (MANUAL) (R&DC)
3. Bubbler airflow (MANUAL) (R&DC)

Bubbler system data was not collected for each run since the system was very stable. Data for various manifold arrangements is given in Table A-11. This data applies for brash icebreaking as well.

Test Results:

Ice properties and vessel response in ice are given in references (2) and (1) respectively. Machinery response for Runs 2231, 2221, and 2210 is contained in reference (3). Hull strains are reported in reference (4). Shaft vibrations and longitudinal accelerations were comparable to level icebreaking without the bubbler system activated.

A plot of bubbler effectiveness in level ice is shown as Figures 8 through 11 of reference (1). Tables 3 through 5 of this reference detail the effectiveness of the bubbler system. The figures and tables are repeated below. In all cases the bubbler system reduced the propeller SHP required to reach the same speed. Propeller SHP reductions ranged from 180 to

1,000 SHP. The bubbler system horsepower averaged about 260 HP. It is important to note that the bubbler system horsepower was essentially constant regardless of the manifold setup so long as the fan speed was reduced when closing off some of the manifolds. The greatest SHP reduction results when all the manifolds are activated. Therefore, the most efficient setup for level icebreaking is to open all the air manifolds. Curves showing the total HP, SHP plus fan HP, have been added to Figures 8 through 11 below. Over most of the power range there is a net power savings from use of the bubbler system.

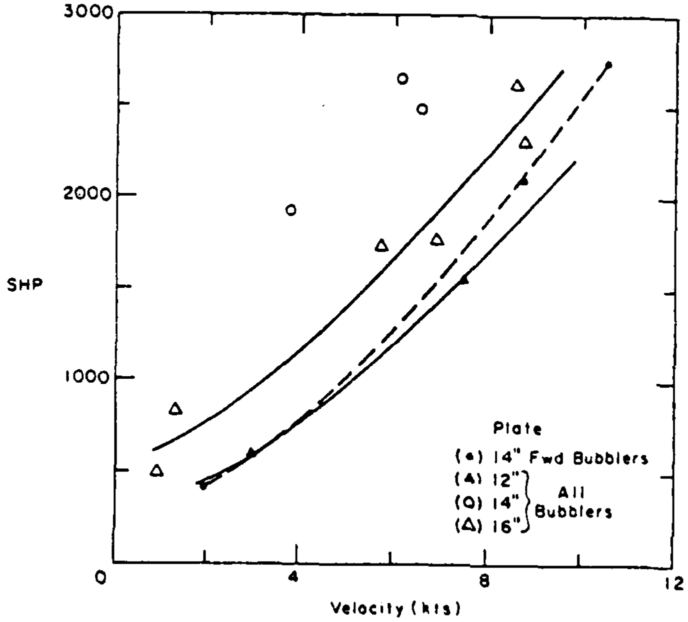


Figure 8. Shaft horsepower vs. velocity in plate ice with all bubblers in operation (3 to 5 in. of snow cover, σ = 12 to 15 kips/ft^2).

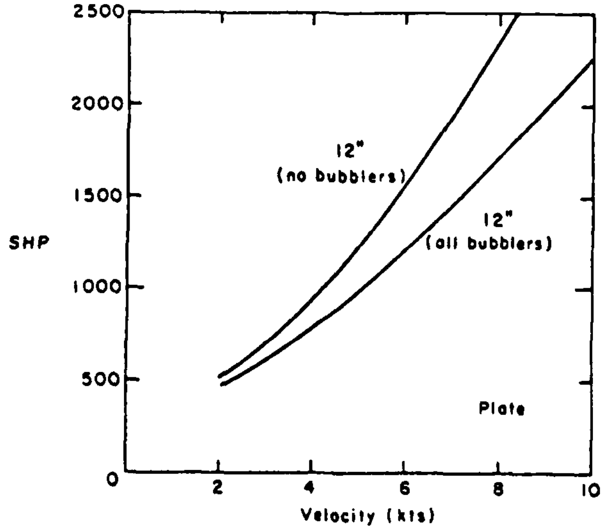


Figure 9. Shaft horsepower vs velocity in plate ice with 3 to 5 in. of snow cover, with aft bubblers or no bubblers in operation.

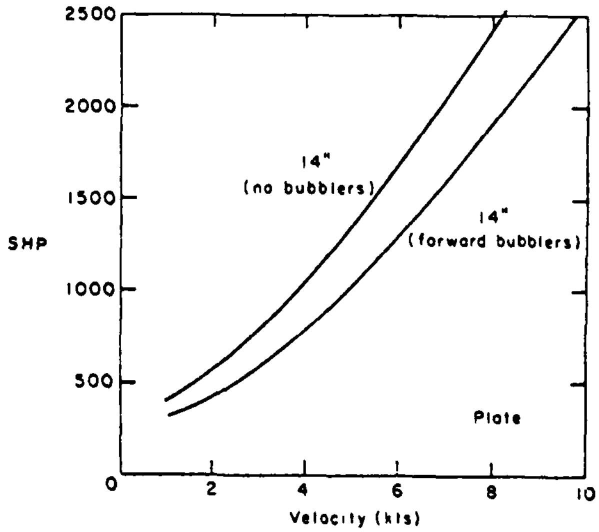


Figure 10. Shaft horsepower vs velocity in plate ice with 3 to 5 in. of snow cover with forward bubblers or no bubblers operating.

Table 3. Bubbler comparison for 12-in. plate ice and 3 to 5 in. of snow.

Vel (kt)	SHP (no bub)	SHP (all bub)	SHP/ %diff	HP Bub	HP Net
2	500	450	50/10	260	-210
4	930	715	215/23	260	-45
6	1550	1200	350/23	260	+90
8	2275	1700	575/25	260	+315

Table 4. Bubbler comparison for 14-in. plate ice and 3 to 5 in. of snow.

Vel (kt)	SHP (no bub)	SHP (fwd bub)	SHP/ %diff	HP Bub	HP Net
2	570	425	145/25	260	-115
4	1050	780	270/26	260	+10
6	1680	1290	390/23	260	+130
8	2440	1900	540/22	260	+280

Table 5. Bubbler comparison for 16-in. plate ice and 3 to 5 in. of snow with intense pressure.

Vel (kt)	SHP (no bub)	SHP (all bub)	SHP/ %diff	HP Bub	HP Net
2	1150	700	450/39	260	+190
4	1850	1230	620/34	260	+360
5	2350	1400	950/40	260	+690

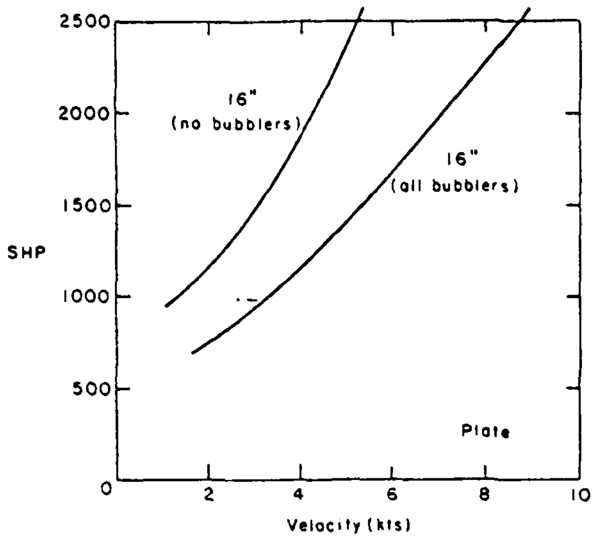


Figure 11. Shaft horsepower vs velocity in plate ice and 3 to 5 in. of snow cover-comparison of performance with all bubblers operating or no bubblers.

There was no discernible difference between the machinery response or hull strains with or without the bubbler system operating.

No tests were conducted with the after manifolds only. However, tests in brash ice indicated that this was a poor manifold arrangement compared to using all the manifolds.

3.3 Brash Icebreaking

Objective:

To determine the cutter's icebreaking capability in brash ice.

Time and Scope of Test Runs:

A total of 34 test runs were made in brash ice between 2.0 and 4.5 feet (0.61 to 1.37 meters) thick. Runs were made on 31 January, 6, 8, and 10 February, and 13 March 1979. Run numbers in the 3000 series apply to these tests. A listing is given in Table A-2.

Data Collected:

The following ice parameters were measured:

1. Percent of surface covered with brash before run (MANUAL) (CRREL)
2. Snow cover thickness (CRREL)
3. Density of brash ice/water mixture (CRREL)
4. Depth of brash (CRREL)

5. Percent of cleared channel covered with ice after run (CRREL)

Machinery and other shipboard data included:

1. Shaft torque (CONT) (including torque variations) (DTNSRDC)
2. Shaft RPM (CONT) (DTNSRDC)
3. Thrust (CONT) (including thrust variations) (DTNSRDC)
4. Ship speed (DIGITAL) (DTNSRDC)
5. Motor volts (DIGITAL) (DTNSRDC)
6. Motor amps (DIGITAL) (DTNSRDC)
7. Time standard (keyed to all data channels) (DIGITAL and CONT) (DTNSRDC)
8. Trim angle (CONT) (R&DC)
9. Ship's draft (MANUAL) (CRREL)
10. Water depth (MANUAL) (R&DC)
11. Hull strains (CONT X8) (DTNSRDC)

CONT(INUOUS) = Analog Data
DIGITAL = Digital Data
MANUAL = Record On Data Form
X8 = 8 Channels of Data

Test Results:

Results of the brash icebreaking tests are detailed in references (1), (2), and (3). Machinery response is shown for Runs 3520, 3430, 3410, and 3500.

Curves of speed versus SHP in brash ice are shown in Figure 20 in reference (1) which has been repeated below. The KATMAI BAY had no difficulty going through any thickness of brash. The ship has enough power to proceed through ice extending to the bottom.

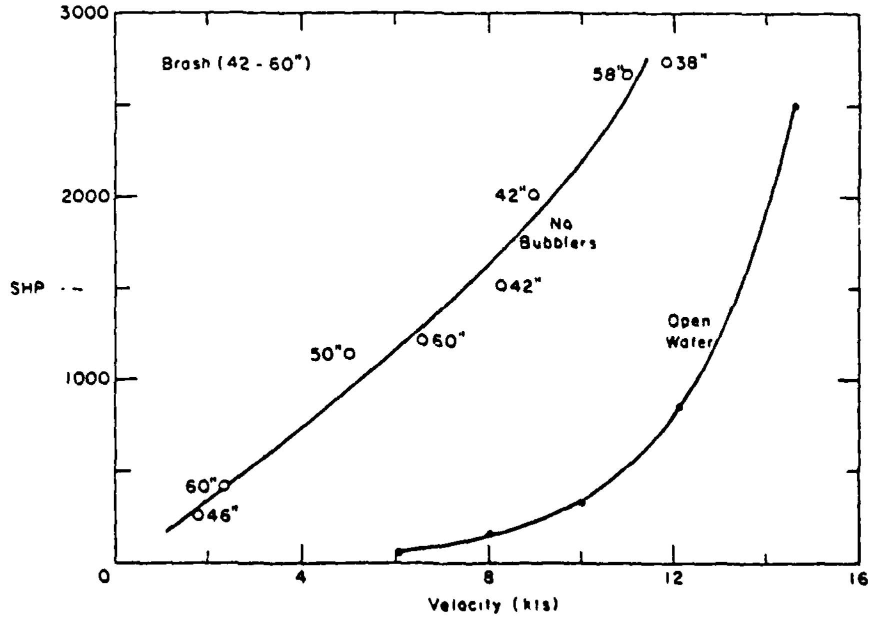


Figure 20. Shaft horsepower vs velocity for 42 to 60 in. of brash ice, 8 February 1979.

No machinery performance problems are evident in the results.

3.4 Bubbler Effects in Brash Ice

Objective:

To determine the effectiveness of the bubbler system in brash icebreaking.

Time and Scope of Test Runs:

Ten runs were conducted with the forward manifolds activated and six with the after manifolds. A total of 24 runs were made with all the manifolds operating. The test runs are listed in Table A-2 and comprise the 4000 series tests.

Data Collected:

The same data was collected as was collected for brash icebreaking with the addition of bubbler system characteristics.

Test Results:

Results are detailed in references (1) through (3). Table A-11 in Appendix A lists the bubbler system characteristics. Speed versus SHP in brash ice is plotted on Figures 18 through 22 in reference (1). Machinery characteristics for Runs 4420, 4310, 4330, and 4300 are given in reference (3). No unusual machinery performance is evident.

Figure 21 below, which comes from reference (1), best shows the effectiveness of the bubbler system in brash ice. These test runs were all made over the same reach and runs were repeated with excellent reproducibili- ty. The benefits for using the bubbler system are listed in Table 8 of the reference. Reductions in SHP between 224 and 700 resulted from a bubbler system horsepower of approximately 260 HP. The greatest savings was at higher speeds with a break-even point on total horsepower occurring between 4 and 6 knots.

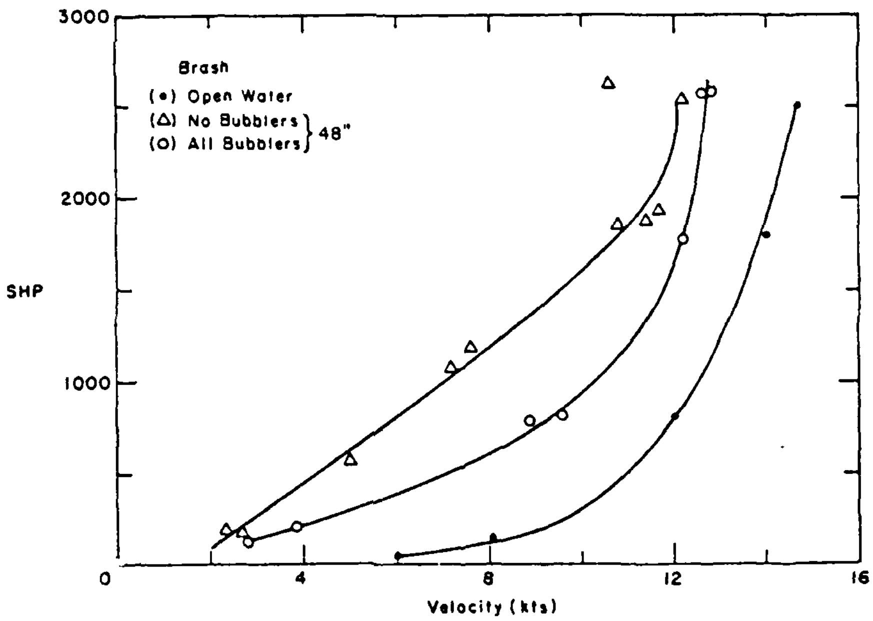


Figure 21. Shaft horsepower vs velocity for 48 in. of brash ice, 10 February 1979.

Table 8. Bubbler comparison in 48-in. brash ice, 10 February 1979.

Vel (kt)	*SHP (no bub)*	*SHP (all bub)*	*ΔSHP %diff*	*HP Bub*	*HP Net*
4	450	225	225/50	260	- 35
6	810	400	410/51	260	+ 150
8	1190	610	580/49	260	+ 320
10	1610	950	660/41	260	+ 400
12	2350	1650	700/30	260	+ 440

Tables 6, 7, and 9 are also from reference (1) and show the results of other brash ice runs. In all of these the bubbler produced less benefits than in the runs cited above.

Table 6. Bubbler comparison in 18- to 22-in. brash ice, 31 January and 1 February 1979.

Vel (kt)	*SHP (no bub)*	*SHP (fwd bub)*	*ΔSHP %diff*	*HP Bub*	*HP Net*	*SHP (all bub)*	*ΔSHP %diff*	*HP Bub*	*HP Net*	*All-Fwd*
4	75	225	150/200	260	-410	180	105/140	260	-365	45/20
6	270	375	105/40	260	-365	270	0	260	-260	105/28
8	510	590	80/16	260	-340	450	60/12	260	-200	140/24
10	870	900	30/4	260	-290	750	120/14	260	-140	150/17
12	1500	1490	10/1	260	-250	1300	200/13	260	-60	190/13

Table 7. Bubbler comparison in approximately 18-in. of varying brash ice, 6 February 1979.

Vel (kt)	SHP (no bub)	SHP (all bub)	ΔSHP/ %diff	HP Bub	HP Net
4	75	270	195/260	260	-455
6	450	660	210/47	260	-470
8	850	1090	240/28	260	-500
10	1300	1550	250/19	260	-510
12	1800	2110	310/17	260	-570

Table 9. Bubbler comparison in 39- to 45- in. brash ice, 13 March 1979.

Vel (kt)	SHP (no bub)	SHP	ΔSHP/ %diff	HP Bub	HP Net	SHP (all bub)	ΔSHP/ %diff	All/Aft	All/Fwd	Aft/Fwd
6	600	400*	200/33	260	- 60	460	140/23	65/12	(60/15)	(125/24)
8	825	800*	25/3	260	-235	750	75/9	75/9	50/6	(25/3)
10	1200	1250*	(50/4)	260	-210	1100	100/8	175/14	150/12	(25/2)
12	1700	1925*	(225/13)	260	-35	1600	100/6	225/12	325/17	100/6
6		525†	75/13	315	-240					
8		825†	0	315	-315					
10		1275†	(75/6)	315	-240					
12		1825†	(125/7)	315	-190					
6		460**	140/23	260	-120					
8		750**	75/9	260	-185					
10		1100**	100/8	260	-130					
12		1600**	100/6	260	-130					

*Forward bubbler
†Aft bubbler
**All bubblers

Limited testing was conducted using the after manifolds alone and the results of these tests could be biased by the failure to reduce the bubbler engine RPM when the forward manifolds were secured. Even with the higher air flow, the after manifolds performed worse than either the forward manifolds or all the manifolds.

3.5 Bollard Pull

Objective:

To determine the limiting ahead and astern thrust capabilities of the cutter.

Time and Scope of Test Runs:

Nine data points were taken to determine the ahead thrust capabilities and seven data points were taken to determine the astern thrust capabilities. These runs are listed in Table A-3. The bollard pull tests were conducted on 19 and 20 March 1979.

Data Collected:

1. Water depth (MANUAL) (R&DC)
2. Water temperature (MANUAL) (R&DC)
3. Location of test (MANUAL) (R&DC)
4. Motor volts (DIGITAL) (DTNSRDC)
5. Motor amps (DIGITAL) (DTNSRDC)
6. Shaft torque (CONT) (DTNSRDC)
7. Shaft RPM (CONT) (DTNSRDC)
8. Thrust (CONT) (DTNSRDC)
9. Line load (DIGITAL) (DTNSRDC)

CONT(INUOUS) = Analog Data
DIGITAL = Digital Data
MANUAL = Record On Data Form

Test Results:

The results of this test are shown in Figure 164 of reference (3) and below. There was no point of thrust breakdown in the RPM range up to full SHP.

A maximum ahead thrust of approximately 55,000 pounds (20,500 kg) was measured. Model tests show an estimated bollard pull of 50,500 pounds at 2500 SHP. These model tests are reported in reference (7).

The maximum astern thrust was measured as 35,000 pounds (13,000 kg). This test had to be conducted alongside a lock wall due to difficulties controlling the position of the vessel. This may have influenced the results slightly. Model test predictions show an astern thrust of 40,000 pounds at 2500 SHP.

3.6 Icebreaking by Ramming

Objectives:

1. To determine the cutter's icebreaking capability in the ramming mode.

2. To determine the ability of the cutter to extract after ramming.

3. To determine the ice loads on the bow framing.

4. To determine the vibration characteristics of the shafting system in the ramming mode

5. To determine the trim of the cutter when ramming and to determine the stability of the cutter when ramming.

6. To determine the propulsion motor behavior in the ramming mode.

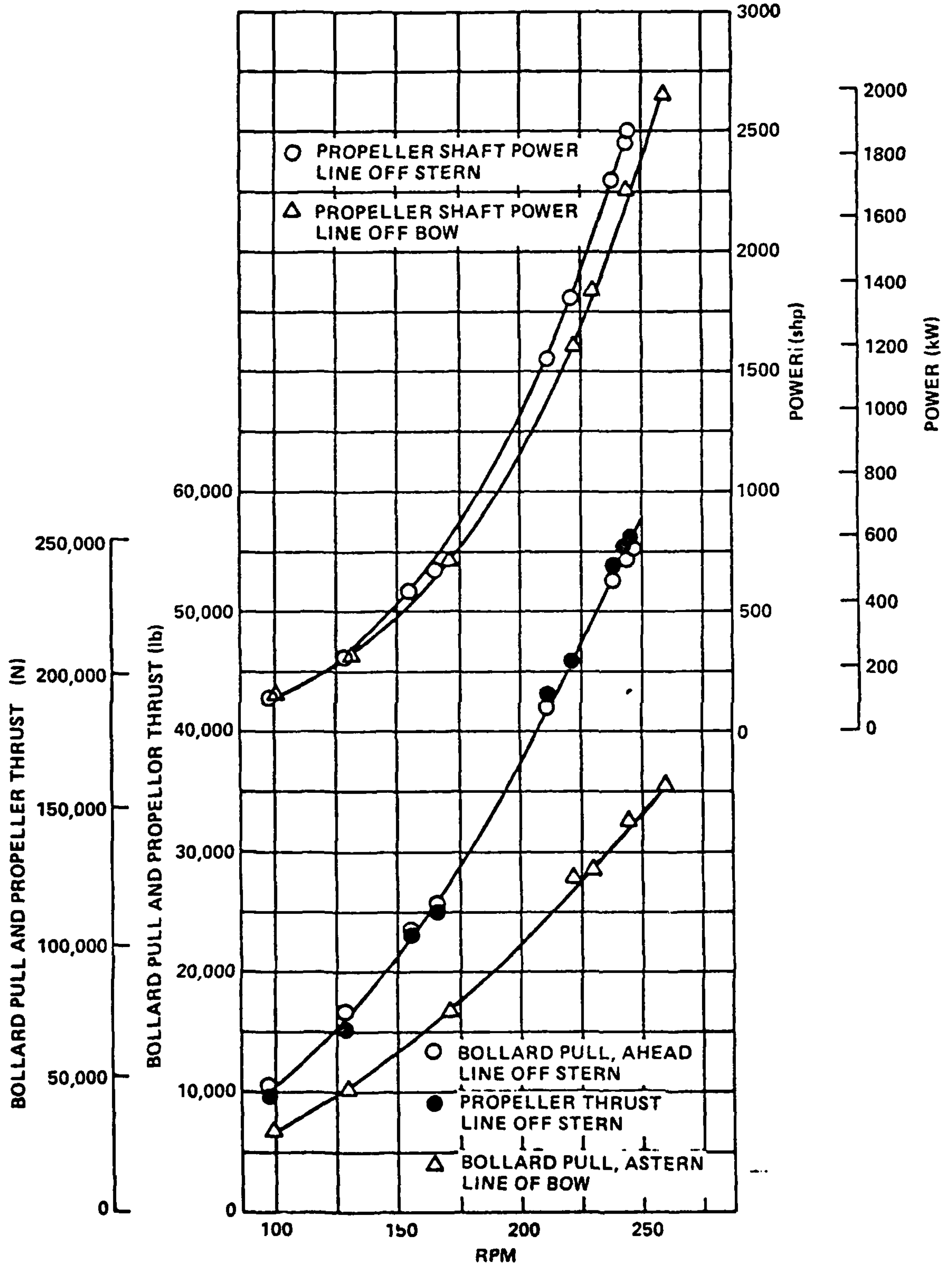


Figure 164 - Bollard Pull, Ahead and Astern

7. To determine the propulsion generator set behavior in the ramming mode.

Time and Scope of Test Runs:

Ramming test runs are delineated in Table A-4. Seven ramming runs were made into ridges on 1 February 1979. The remainder of the tests were conducted in level ice between 22 and 35 inches (56 to 89 cm) thick on 17 March 1979. This level ice had a nearly uniform temperature distribution and was, therefore, weaker than the ice encountered earlier in the test program.

Data Collected:

The following parameters were measured by the ice party:

1. Thickness (CRREL)
2. Temperature Profile (CRREL)
3. Salinity (if appropriate) (CRREL)
4. Snow cover thickness (CRREL)
5. Hull friction (CRREL)
6. Density (CRREL)
7. Penetration distance (CRREL)
8. Mass of ice ridge (if appropriate) (CRREL)

The water depth and ship's draft were also recorded.

Data collected on the vessel included the following:

1. Approximate number of ship lengths from ice edge at start (MANUALLY) (R&DC).
2. Shaft torque (CONT) (including torque variations) (DTNSRDC)
3. Shaft RPM (CONT) (DTNSRDC)
4. Thrust (CONT) (including thrust variations) (DTNSRDC)
5. Ship speed (DIGITAL) (DTNSRDC)
6. Motor volts (DIGITAL) (DTNSRDC)
7. Motor amps (DIGITAL) (DTNSRDC)
8. Motor exc. volts (DIGITAL) (DTNSRDC)
9. Motor exc. amps (DIGITAL) (DTNSRDC)
10. Motor temperature (DIGITAL) (DTNSRDC)
11. Time standard (keyed to all data channels) (DIGITAL and CONT) (DTNSRDC)
12. Generator RPM (DIGITAL X2) (DTNSRDC)
13. Generator volts (DIGITAL X2) (DTNSRDC)
14. Generator amps (DIGITAL X2) (DTNSRDC)
15. Generator exc. volts (DIGITAL X2) (DTNSRDC)
16. Generator exc. amps (DIGITAL X2) (DTNSRDC)
17. Starboard generator temperature (DIGITAL) (DTNSRDC)
18. Trim angle (CONT) (R&DC)
19. Hull strains (CONT X8) (DTNSRDC)
20. Longitudinal acceleration (CONT) (R&DC)

CONT(INUOUS) = Analog Data
DIGITAL = Digital Data
MANUAL = Record On Data Form
X2 = 2 Channels of Data

Test Results:

Ramming performance with regard to acceleration in an ice-filled channel and penetration is detailed in reference (1). Reference (2) explains the ice conditions in which the tests were conducted. Machinery response for two runs, Numbers 6500 and 6612, are shown in reference (3). Hull strains for 16 of the runs are given in reference (4). Shaft vibrations were not measured during the ramming runs due to the low levels measured during open water and level ice trials. No severe vibrations were noticeable during the ramming runs.

As shown in Table A-4, test runs were conducted with various bubbler manifold combinations. It appears that there is some advantage to be gained by using the bubbler system during ramming; however, the best manifold arrangement is not clear from the data. The bubbler system greatly reduced the power required to extract after a ram but less than 1200 SHP was required to extract without the bubbler system activated. The vessel usually slid back off the ice without astern power being applied.

Machinery responded very well to the varying conditions of the ramming runs. There was no evidence of instability with any of the parameters measured.

Acceleration distance in a channel in level ice is shown in Figure 24 from reference (1). This figure is given below.

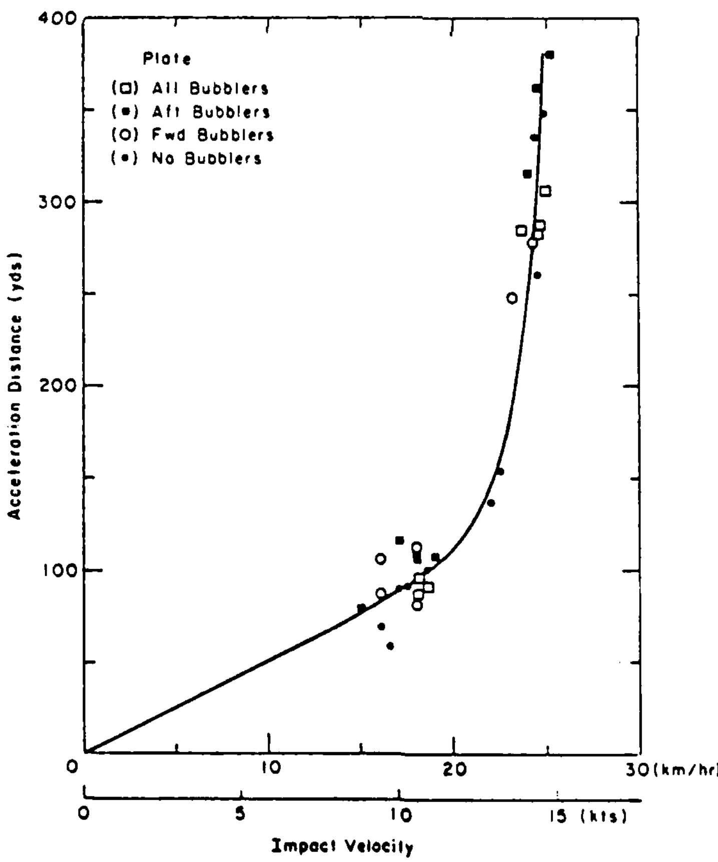


Figure 24. Acceleration distance in a channel in plate ice, 17 March 1979.

Bending strains on the stiffeners in the bow reached levels from 50 to 100 percent higher during ramming runs than during level ice runs. The strains experienced during ramming were not excessive even though the ramming runs were conducted with impact speeds in excess of designed impact speeds. A maximum bending stress of 27.0 KSI was measured at the middle of Frame 18. A maximum shear stress of 21.6 KSI was measured at the upper connection of Frame 18.

Figure 1 below shows the vessel motion response during two typical ramming runs. There was no evidence of vessel instability during ramming. The cutter seldom got stuck in the ice after a ram and its drafts were never obtained in this condition.

3.7 Comparison Test With 110' WYTM

Objective:

To compare the icebreaking potential of the 140' cutter to that of the 110' WYTM.

Time and Scope of Test Runs:

A single side-by-side comparison run was made on 9 February 1979.

Data Collected:

16mm motion pictures were taken from a helicopter of the two ships. This is the only documentation for this test.

Test Results:

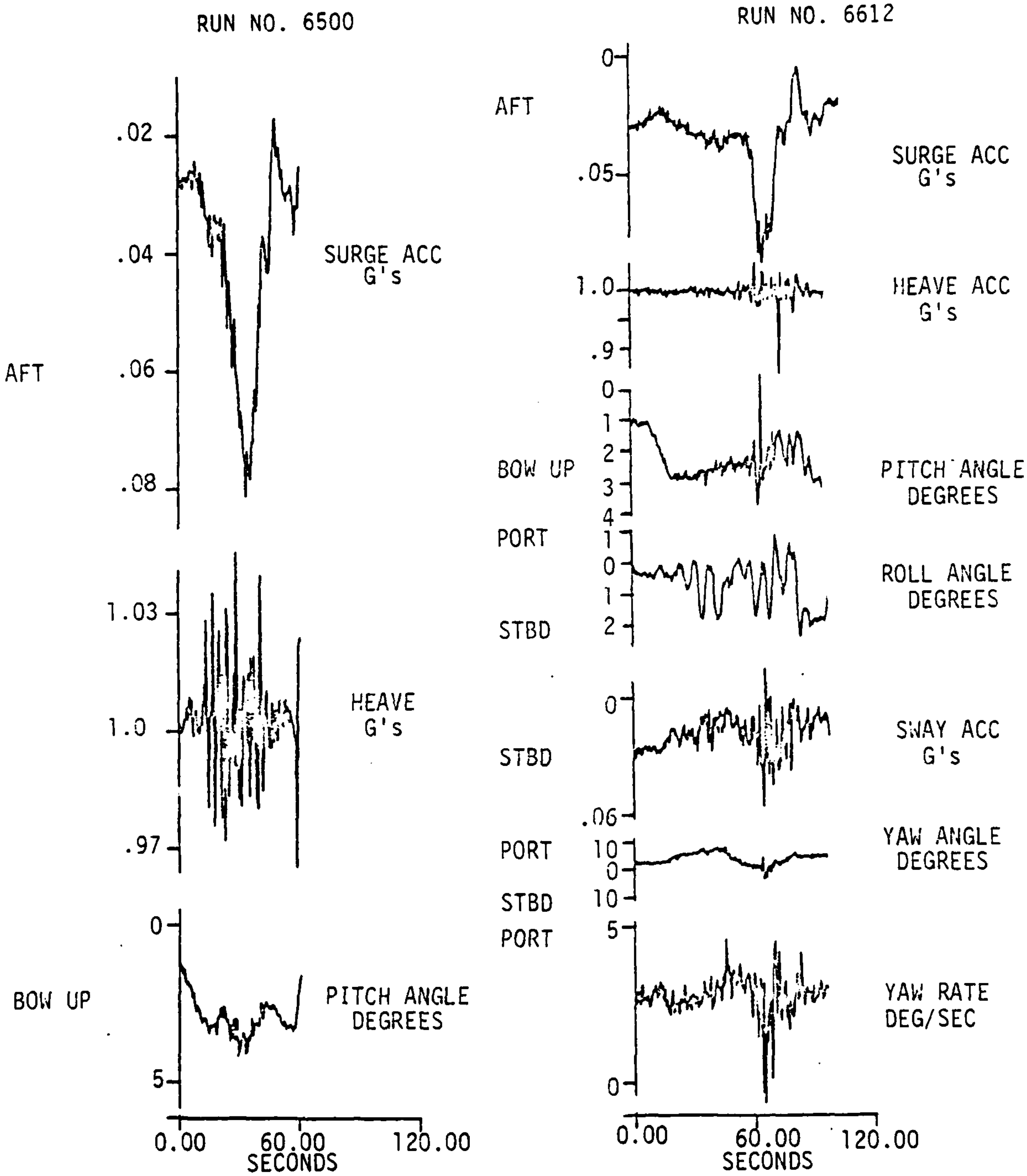
In the brash ice channel on the way to the test site the KATMAI BAY was able to match speed with the USCGC ARUNDEL (WYTM-9[illegible]), when the ARUNDEL was at full ahead and the KATMAI BAY was at 6/10 speed ahead (Control lever Position 6). At one point the KATMAI BAY, at full power, passed the ARUNDEL by running through the thick refrozen brash at the channel edge while the ARUNDEL proceeded at full power up the channel.

The level ice comparison test took place in 14 inches (36 cm) of ice with approximately 5 inches (13 cm) of snow cover. After 11 minutes running the KATMAI BAY was approximately one mile ahead of the ARUNDEL. ARUNDEL had to back and ram while the KATMAI BAY proceeded at about 6 knots with the bubbler system activated and about 5 knots with the bubbler system secured.

3.8 Maneuvering in Level Ice

Objective:

To determine the maneuvering capability in continuous icebreaking as well as rudder loads.



RUN NO. 6500
.02
.04
SURGE ACC
G's
AFT
.06
.08
1.03
HEAVE
G's
1.0
.97
0
BOW UP
PITCH ANGLE
DEGREES
5
0.00
60.00
120.00
SECONDS
RUN NO. 6612
0
AFT
.05
SURGE ACC
G's
1.0
HEAVE ACC
G's
.9
0
1
2
BOW UP
3
4
PITCH ANGLE
DEGREES
PORT
1
0
ROLL ANGLE
DEGREES
1
STBD
2
0
SWAY ACC
G's
STBD
.06
YAW ANGLE
DEGREES
PORT
10
0
STBD
10
PORT
5
YAW RATE
DEG/SEC
0
0.00
60.00
120.00
SECONDS

FIGURE 1

Time and Scope of Test Runs:

Two test runs were conducted on 9 February 1979. One turn was made to the left and one to the right. Runs were made at full power and full rudder.

Data Collected:

The following data was collected:

1. Ice thickness (CRREL)
2. Ice temperature profile (CRREL)
3. Ice salinity (if appropriate) (CRREL)
4. Snow cover thickness (CRREL)
5. Hull friction (CRREL)
6. Ice density (CRREL)
7. Hull roughness (CRREL)
8. Water depth (MANUAL) (R&DC)
9. Shaft torque (CONT) (including torque variations) (DTNSRDC)
10. Shaft RPM (CONT) (DTNSRDC)
11. Thrust (CONT) (including thrust variations) (DTNSRDC)
12. Ship's speed (DIGITAL) (DTNSRDC)
13. Motor volts (DIGITAL) (DTNSRDC)
14. Motor amps (DIGITAL) (DTNSRDC)
15. Time standard (keyed to all data channels) (DIGITAL and CONT) (DTNSRDC)
16. Precision position plot (every 30 seconds) (DIGITAL) (DTNSRDC)
17. Yaw rate (CONT) (R&DC)
18. Trim angle (MANUAL) (R&DC)

CONT(INUOUS) = Analog Data
DIGITAL = Digital Data
MANUAL = Record On Data Form

Test Results:

Ice information is contained in reference (2). The turning properties are reported in reference (3). The ship has a turning diameter of approximately 125 to 150 yards (114 to 137 m) in about 17 inches (43 cm) of level ice. This compares to a tactical diameter at full power and 30^{o} rudder in open water of 162 to 174 yards (148 to 159 m).

Figures 148 and 149 below come from reference (3) and show the turns. The rough shape of the turns was a result of the bow following ice leads which opened during the turn. Rudder ram pressures are given in Figures 152 and 153 of reference (3).

3.9 Maneuvering in Brash Ice

Objective:

To determine the maneuvering capability of the cutter in brash ice and the rudder loads.

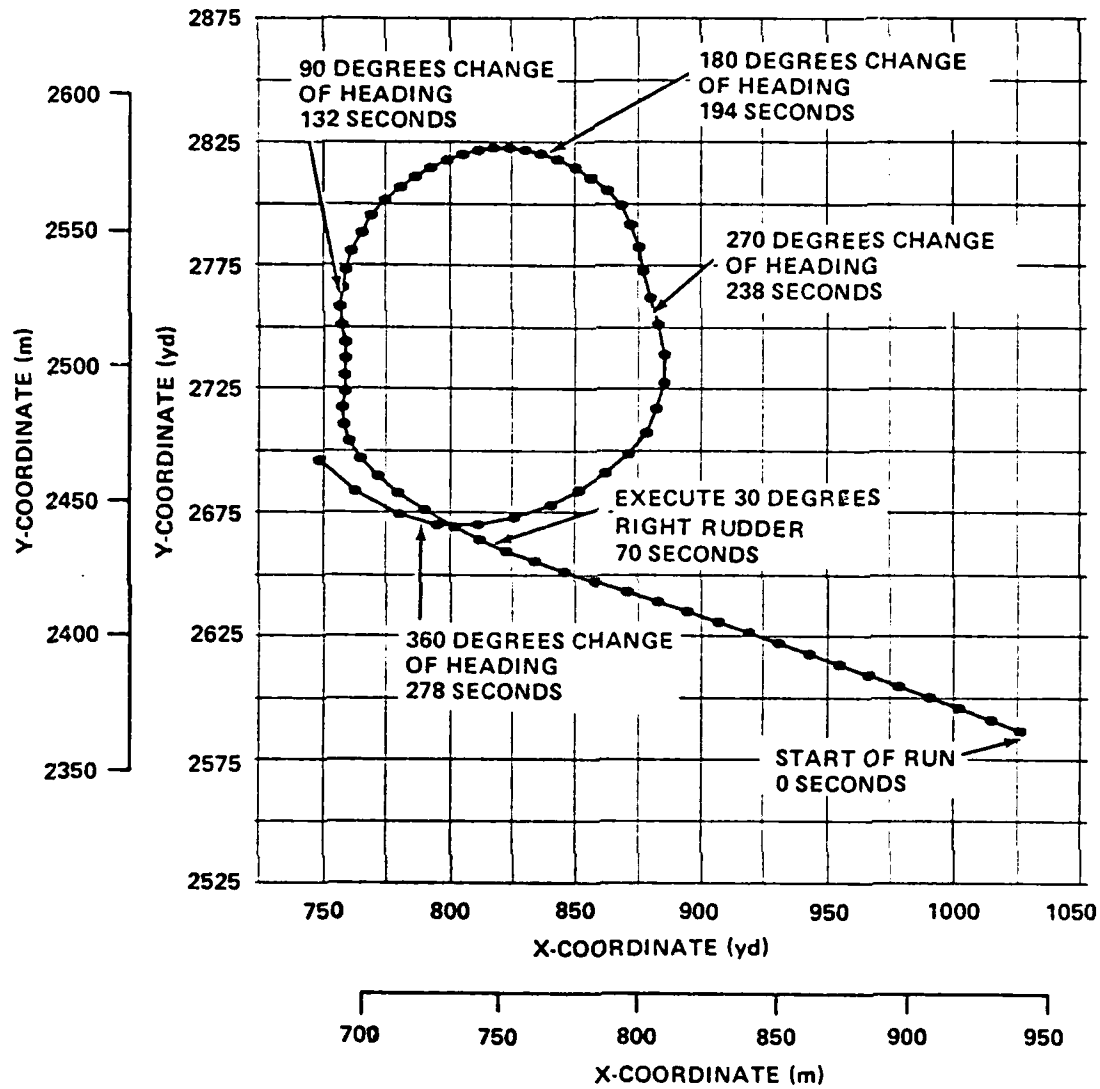


Figure 148 - Ship Track, Maneuvering in Level Ice, 30-Degree Right Rudder, Run 8000

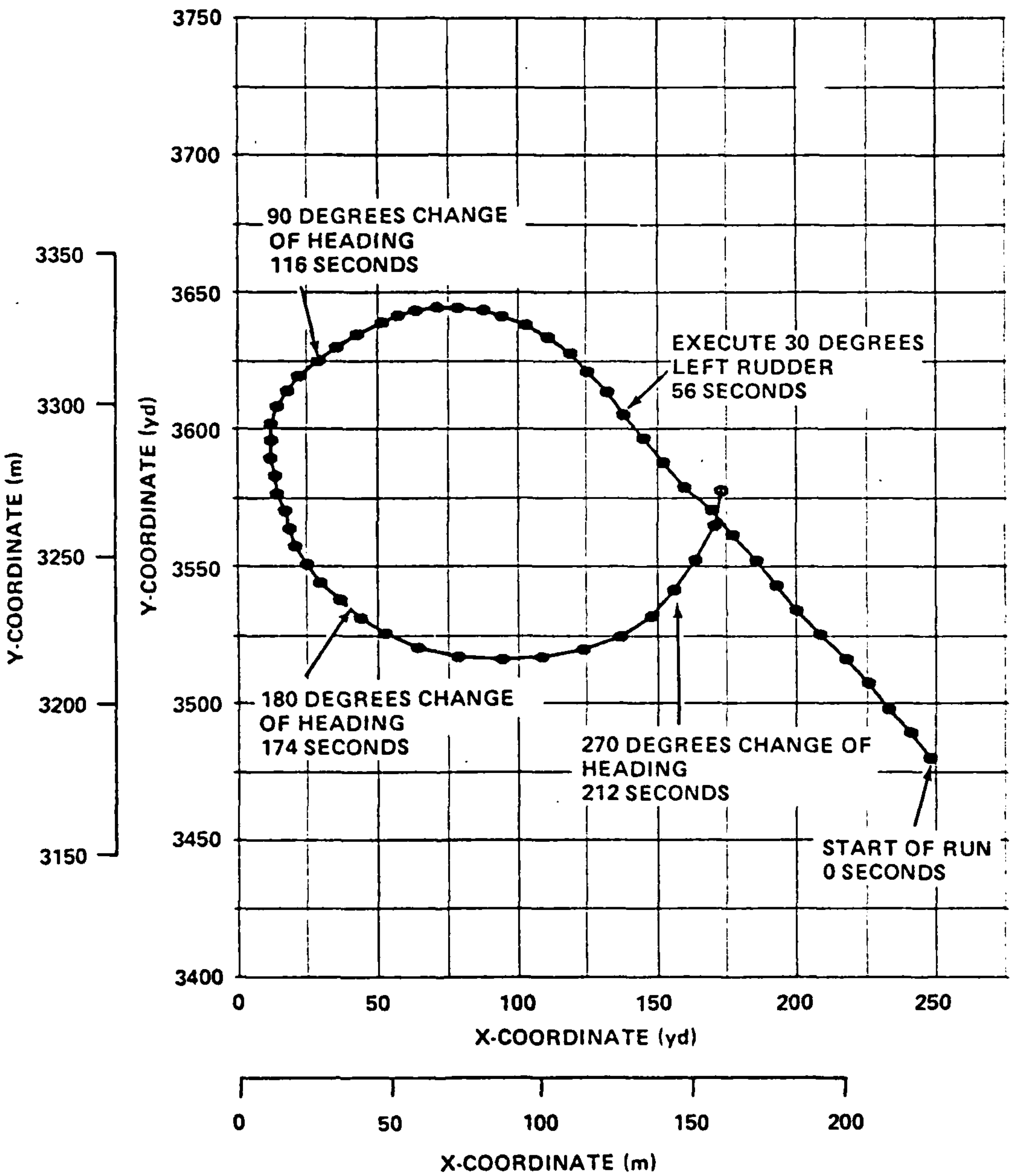


Figure 149 - Ship Track, Maneuvering in Level Ice, 30-Degree Left Rudder, Run 8110

Time and Scope of Test Runs:

Two test runs were conducted on 17 March 1979 in a brash ice basin carved by the ship. The brash ice thickness was not great. The rudder ram pressures were not measured. Runs were conducted at full power and full rudder.

Data Collected:

Brash ice property data was estimated. Machinery and other data is similar to level ice maneuvering.

Test Results:

A turning diameter very nearly equal to the open water tactical diameter was obtained. No unusual machinery properties were noted. Reference (3) contains plots of the test data in Figures 154 and 155.

3.10 Shaft/Propeller Validation

Objective:

To determine the vibration characteristics of the shafting system and the propeller thrust in open water.

Time and Scope of Test Runs:

A total of 21 test runs were made on 13 February 1979 using various shaft RPMs as well as turns to port and starboard. These test runs are listed in Table A-6. Shafting system vibration tests were conducted in accordance with MIL-STD-167-2 for Types III and IV vibration.

Data Collected:

The following data was collected:

1. Shaft torque (CONT) (including torque variations) (DTNSRDC)
2. Shaft RPM (CONT) (DTNSRDC)
3. Shaft thrust (CONT) (including thrust variations) (DTNSRDC)
4. Thrust bearing horizontal acceleration frequency and amplitude (CONT) (DTNSRDC)
5. Thrust bearing vertical acceleration frequency and amplitude (CONT) (DTNSRDC)
6. Thrust bearing longitudinal acceleration frequency and amplitude (CONT) (DTNSRDC)
7. Ship drafts (R&DC)

CONT(INUOUS) = Analog Data
DIGITAL = Digital Data
MANUAL = Record On Data Form

Test Results:

Results of this test are covered in reference (5). All vibrations and stresses were well below the limits set in MIL-STD-167-2. There were no critical frequencies discernable within the operating range of shaft RPM.

3.11 Seakeeping Analysis Validation

Seakeeping tests were conducted off the Virginia Capes with the USCGC MOBILE BAY (WTGB-103) in September 1979. These tests will be the subject of a separate report.

3.12 Rudder Torque Validation

Objective:

To determine the forces on the rudder during turns in open water.

Time and Scope of Test Runs:

Twelve turning tests were made on 13 February 1979 in open water. These runs are listed in Table A-7.

Data Collected:

The following data was collected:

1. Rudder ram pressures (CONT) (DTNSRDC)
2. Rudder angle (MANUAL) (DTNSRDC)
3. Ship speed (MANUAL at twenty-second intervals) (DTNSRDC)

Test Results:

Plots of rudder ram pressures and rudder angle are given in reference (3). A maximum pressure differential of about 400 psi was measured during an ahead turn at 12 knots. The maximum pressure differential approached 700 psi during an astern turn at 10 knots. In both cases the maximum pressure differential occurred when the rudder had reached full travel and had to be stopped.

3.13 Directional Stability Validation

Objective:

The objective of this test was to characterize the response of the cutter to its rudder and to identify any control difficulties.

Time and Scope of Test Runs:

Trials were conducted on 9 and 10 July 1979. A total of four trial runs were conducted. Ahead spiral maneuvers were run at 5 knots and 10 knots and astern spiral maneuvers were run at 5 knots and 10 knots. Wind speed during the test was less than 8 knots and seas were less than 1 foot. Water depth was approximately 200 feet.

Data Collected:

Both yaw rate and heading angle were recorded using a gyro stabilized platform. This information together with the time required for the ship's heading to swing through 5 or 10 degrees provide three independent measurements of yaw rate. The rudder angle was obtained from the bridge repeater.

Test Results:

The yaw rate steadied rapidly. Because yaw rate was directly measured, it was possible to tell accurately when it had steadied out without waiting a preset amount of time.

The results of this test are presented in Figures 2 and 3 below. No plot was made of the low speed astern spiral maneuver because the ship backed into the wind and did not respond to the rudder. Data points are given in Tables A-12, A-13, A-14, and A-15. The yaw rates presented were taken from the gyro stabilized platform. The other two measures of yaw rate agreed closely to these values.

The ship shows a stable response characteristic at both ahead speeds. At 10 knots astern the rudder has some effect but the response is very unstable. Once the ship's stern starts swinging to port, no amount of right rudder will cause it to swing back to starboard. At 5 knots astern the rudder has no effect and the ship will back into the wind. These characteristics are considered to be typical of a single-screw vessel of the same size as the 140-foot WTGB.

3.14 Speed Versus RPM

Objective:

To determine the speed versus RPM curve for the 140' WTGB class.

Time and Scope of Test Runs:

Sixteen test runs were conducted on 9 July 1979 in Pendill's Bay located at the southern end of Lake Superior's Whitefish Bay. Water currents were negligible and wind speed was approximately 5-8 knots. The tests were conducted in approximately 150 feet (45.7 m) of water. Tests were conducted alternately into the wind and downwind.

Data Collected:

Instrumentation used is described in reference (6). Ship position and shaft RPM were recorded by a digital computer. The position data was processed to obtain ship speed.

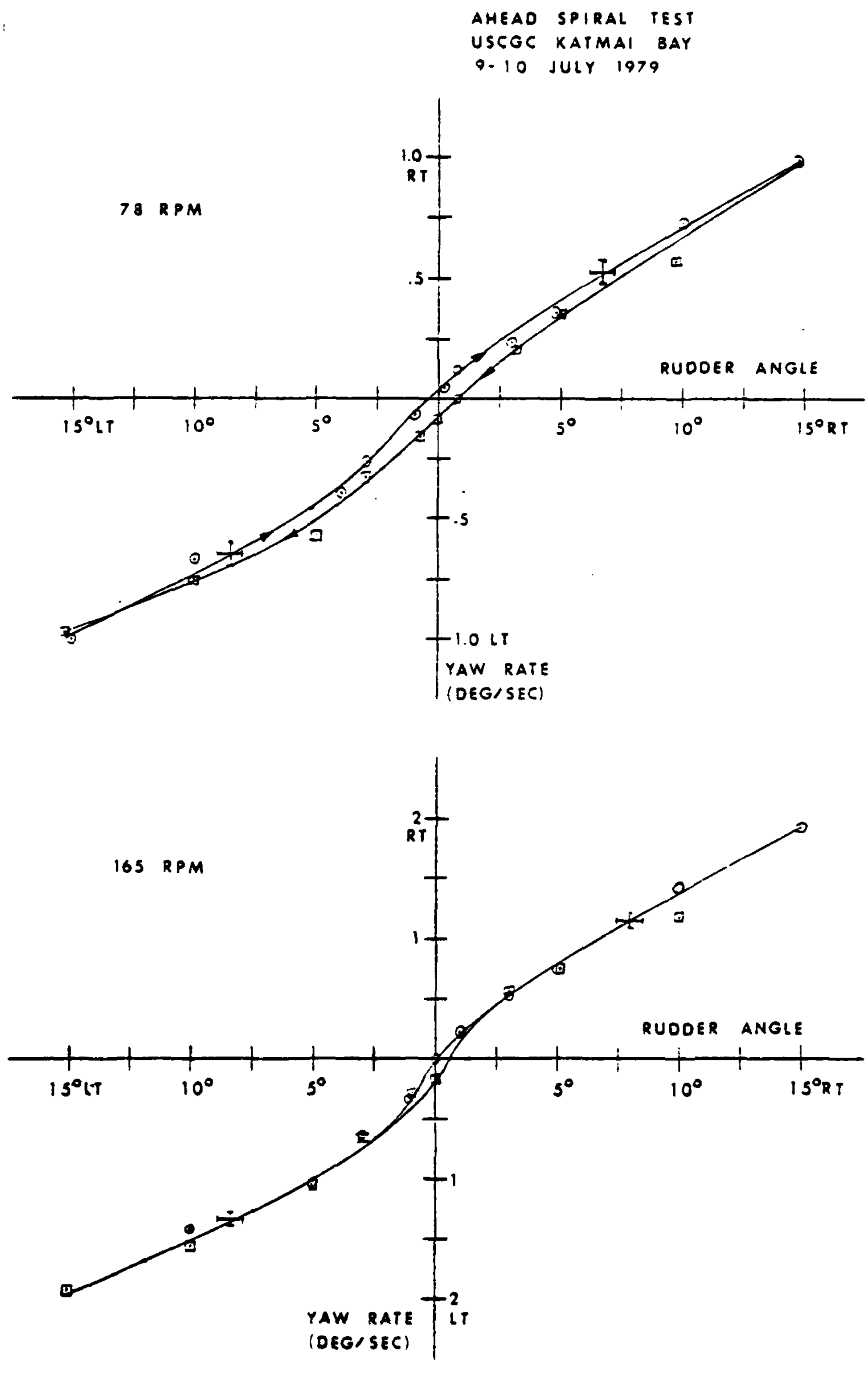

AHEAD SPIRAL TEST
USCGC KATMAI BAY
9-10 JULY 1979
78 RPM
1.0
RT
.5
-.5
1.0 LT
YAW RATE
(DEG/SEC)
RUDDER ANGLE
15°LT
10°
5°
5°
10°
15°RT
165 RPM
2
RT
1
1
2
LT
YAW RATE
(DEG/SEC)
RUDDER ANGLE
15°LT
10°
5°
5°
10°
15°RT

FIGURE 2

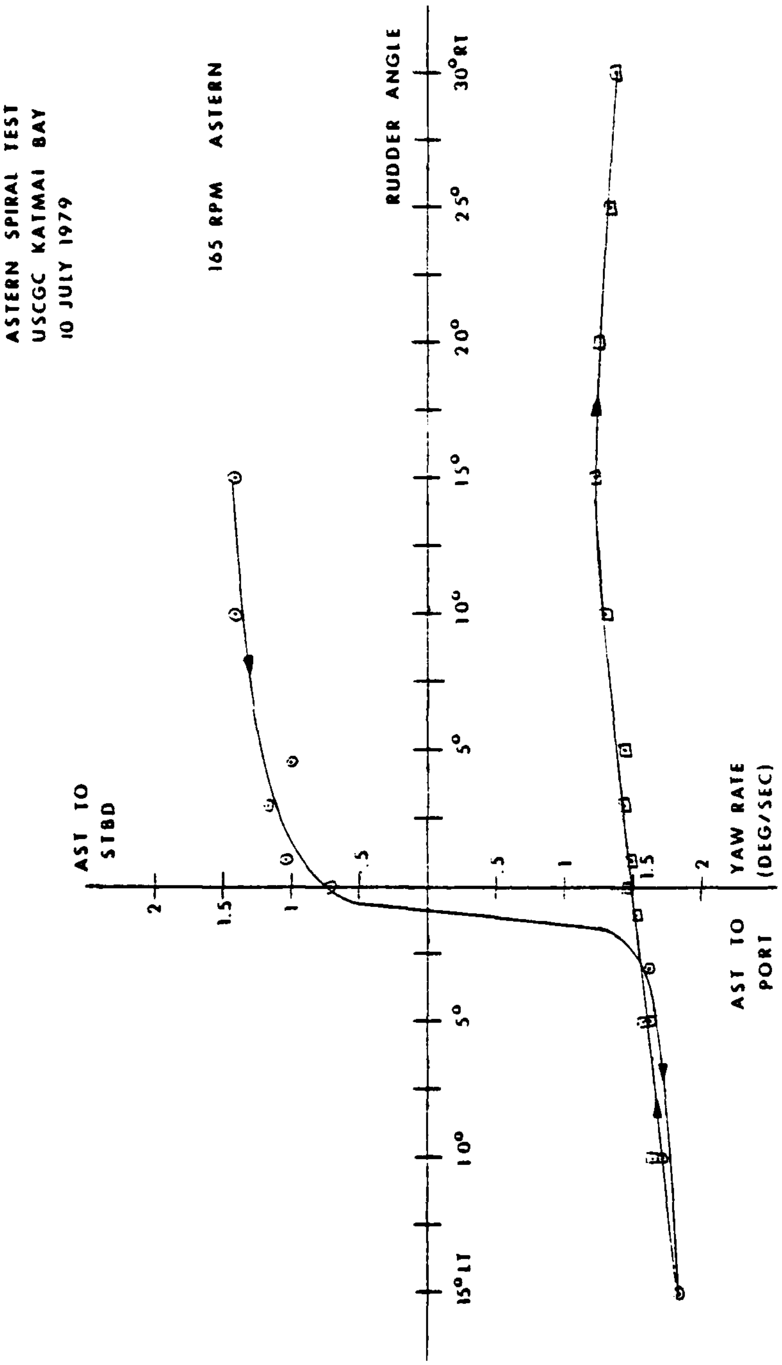

ASTERN SPIRAL TEST
USCGC KATMAI BAY
10 JULY 1979
165 RPM ASTERN
RUDDER ANGLE
30° RT
25°
20°
15°
10°
5°
5°
10°
15° LT
AST TO STBD
AST TO PORT
YAW RATE (DEG/SEC)
2
1.5
1
.5
.5
1
1.5
2

FIGURE 3

Test Results:

The ship's speed versus RPM plot is shown in Figure 1 of reference (6). The cutter obtained a maximum speed of 14.7 knots at an average RPM of 303.7. Trials run upwind and downwind at the same RPM had nearly identical speeds.

3.15 Bubbler Effect with Shaft Stopped

Objective:

To determine the vessel speed and direction when the shaft is stopped and the air bubbler system is activated.

Time and Scope of Test Runs:

Two trials were performed as shown in Table A-10. These tests took place on 9 July 1979. The vessel was allowed to reach steady-state conditions before data collection began. All bubbler manifolds were activated.

Data Collected:

The position of the ship was plotted for 388 secs in each run.

Test Results:

The vessel backed to starboard making approximately a 270-degree heading change during each of the two runs. Test results are discussed in reference (6). A speed of 1.1 knots astern occurred. Since only 20 SRPM ahead is required to compensate for this astern thrust, it is unlikely that it has a serious detrimental effect on ship performance in ice. It is apparent that the thrust was not equal on each side of the ship. Balancing the air flow might improve performance in ice.

3.16 Turning in Open Water

Objective:

To determine the tactical diameter, advance, and transfer during turns in open water for various speeds and rudder angles.

Time and Scope of Test Runs:

A total of 18 turns were made as shown in Table A-10. Three speeds were used and three rudder angles. Turns were made to port and starboard.

Data Collected:

Ship's position was plotted and shaft RPM, rudder angle, and ship's heading were recorded digitally.

Test Results:

Results are detailed in reference (6). Table 3 and Figures 2 through 5 of the reference contain this information. Wind and current had minimal effect on the turning data and very consistent results were obtained. The tactical diameters, advance, and transfer remained nearly constant for all ship speeds. Table 3 is shown below.

3.17 Crash Stops and Crash Reversals

Objective:

1. To determine the distance and time required to stop the vessel from various ahead speeds.

2. To determine the distance and time required to reverse the vessel from full ahead to full astern and from full astern to full ahead.

Time and Scope of Test Runs:

All tests were conducted on 10 July 1979. Four crash stops and three full reversals were made as listed in Table A-10.

Data Collected:

The following data was collected:

1. Ship's position
2. Shaft RPM
3. Time

Test Results:

A plot of stopping distance and time is given in reference (6), Figure 6. Twenty seconds were required to stop from 5 knots over a reach of 38 yards (35 m). From 14.8 knots the comparable values are 44 seconds and 208 yards (192 m).

Both runs from full ahead to full astern were terminated early and reversing times are not available. Reversing from full astern to full ahead was done and the results are plotted in Figure 7 of reference (6).

3.18 Photo Documentation

Photo documentation was made of each of the types of icebreaking. This documentation consisted of 16mm motion pictures and 35mm slides. All of this documentation has been transmitted to the Naval Engineering Division of Coast Guard Headquarters for further processing and distribution.

TABLE 3 - USCG CUTTER KATMAI BAY (WTGB-101), SUMMARY OF TACTICAL DATA

Run No.	Rudder Angle (deg)	Approach Course (deg)	Speed (knot) Approach	Speed (knot) Turn	Approach rpm	Advance (yd)	Advance (m)	Transfer (yd)	Transfer (m)	Tactical Diameter (yd)	Tactical Diameter (m)	Circle Diameter (yd)	Circle Diameter (m)	Time at 360° (s)
201	9.5 R*	263	5.0	4.4	81	294	269	189	173	420	384	405	370	514
202	19.5 R	268	5.5	3.6	79	160	146	125	114	242	221	222	203	340
203	29.5 R	264	5.5	2.9	78	118	108	74	68	172	157	153	140	292
204	10.0 L	262	5.0	4.3	80	241	220	187	171	386	353	365	334	473
205	20.0 L	262	5.0	3.4	80	164	150	94	86	212	194	199	182	326
206	28.5 L	262	5.3	2.9	80	136	124	71	65	166	152	147	134	280
207	10.5 L	263	9.9	9.2	164	278	254	206	188	431	394	431	394	263
208	20.0 R	263	9.9	7.6	164	166	152	103	94	234	214	224	205	165
209	30.0 R	263	9.9	6.3	164	149	136	72	66	171	156	157	144	139
210	9.7 R	263	10.0	9.2	164	262	240	192	176	397	363	391	362	241
211	20.5 L	262	10.0	7.5	164	180	165	101	92	225	206	215	197	161
212	29.5 L	261	9.9	6.1	164	150	137	68	62	164	150	151	138	139
213	10.5 R	263	14.6	14.3	304	270	247	190	174	410	375	420	384	164
214	19.5 R	263	14.8	12.8	304	177	162	103	94	236	216	238	218	104
215	29.5 R	263	14.7	11.2	304	155	142	77	70	174	159	162	148	81
216	9.5 L	263	14.6	14.2	304	284	260	203	186	423	387	422	386	166
217	18.7 L	262	14.7	12.7	304	165	151	103	94	227	208	225	206	99
218	28.5 L	263	14.8	10.6	304	140	128	83	76	162	148	150	137	79

*R is right; L is left.

CONCLUSIONS AND RECOMMENDATIONS

4.1 Ship Performance In Ice

The USCGC KATMAI BAY (WTGB-101) met or exceeded design predictions for performance in all types of ice and machinery performed excellently with no instabilities or overloads. The icebreaking ability of this class of cutter far exceeds that of the 110' WYTM which it will replace.

4.2 Bubbler Benefits

Use of the installed bubbler system resulted in shaft horsepower reductions which exceeded the horsepower requirements of the bubbler system in both level and brash ice in most cases. The bubbler system also was beneficial in backing down after a ramming run as it reduced the friction between the hull and ice and also washed snow and small pieces of ice clear of the ship's sides.

4.3 Ship Performance in Open Water

Stability and tactical data tests indicate that the 140' WTGB is directionally stable ahead and has good turning and stopping performance.

4.4 Vibrations

No severe shaft vibrations were present during open water operation. MIL-STD-167-2 applies only for open water operation and its requirements were easily satisfied.

4.5 Structural Strength

The limited hull strain measurements made indicated no excessive hull stresses and no damage to the hull structure occurred. The structure apparently is of adequate strength.

It is important to note that the data reported is the result of a very limited effort.

The selection of the areas to be instrumented was influenced by their accessibility and a requirement for not disturbing or contaminating the fresh water tanks between frames 18 and 27.

Cost considerations allowed for instrumentation of only two spans of transverse frames at the bow icebelt. This explains to some extent the observations reported that indicate a reduction in load with increasing speed and pitch angle.

The profile shown below shows a more accurate picture of the strain gage locations that are addressed in the report. Notice that as the pitch angle increases to the 7.5 degrees maximum reported, the instrumented vertical frame spans in fact come up away from the ice, thus showing lesser strains.

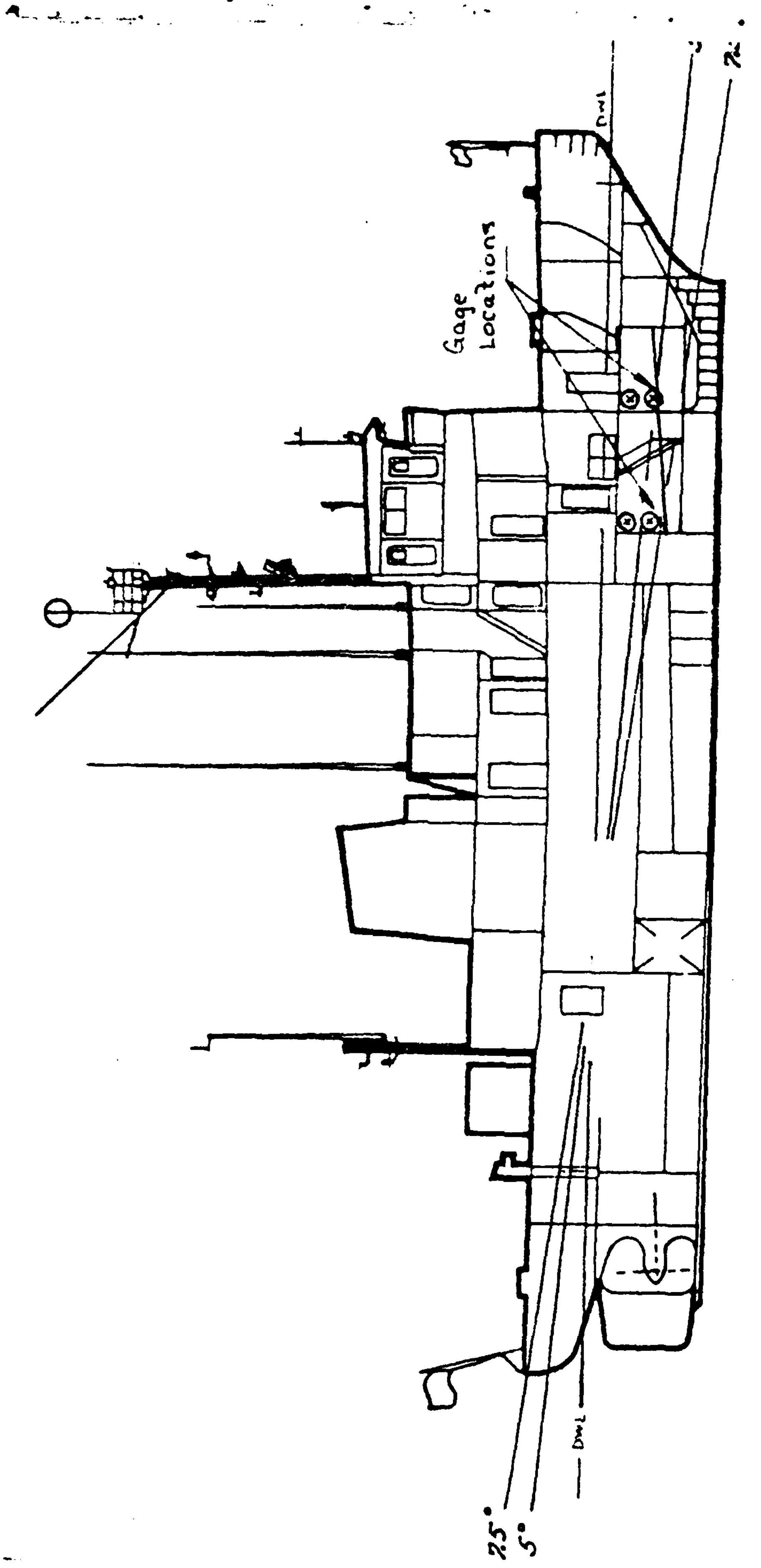


FIGURE 4.

Pitch angle was measured but the rise in the ship's center of gravity was not obtained. It was planned to integrate the heave acceleration data to determine the rise in the center of gravity but in practice this proved unreliable. The rise in center of gravity was approximately one to two feet based on observations of the ice party.

Structural instrumentation, calibration, data gathering, and analysis is costly and there will always be a need to obtain data with a minimum amount of instrumentation. The selection of the areas to be monitored should not be made until after ship attitude data is gathered and load areas are identified.

4.6 Self-Propelled Model Test

A very complete record was made of the power input to the motor and into the shaft. If data was available on the thrust deduction in ice at the various power levels and speeds, the resistance of the ship could also be calculated since thrust and speed were recorded. It is recommended that self-propelled model tests be conducted to obtain this information. The effect of ice on the thrust deduction has never been studied.

APPENDIX A

LISTING OF TESTS

TABLE A-1 - LEVEL ICE TESTS

EST MBER	TYPE OF TEST	ICE THICKNESS (inches)	APPROX SPEED (knots)	APPROX SHP	CONTROL SETTING	DATE	TIME	COMMENTS
000	Level Ice, No Bubbler	12	1.9	500	5	1/30	1314	(1)
010	" ", " "	15	5.6	1420	7	1/30	1326	(1)
020	" ", " "	11	7.8	2240	9	1/30	1337	(1)
030	" ", " "	11	8.8	2720	10	1/30	1347	(1)
100	" ", " "	14	1.0	370	5	1/31	1311	(2)
110	" ", " "	15	5.4	1490	7	1/31	1315	(2)
120	" ", " "	14	7.7	2380	9	1/31	1330	(2)
130	" ", " "	15	9.0	2700	10	1/31	1340	(2)
200	" ", " "	15	5.5	1360	6	1/31	1546	
210	" ", " "	13	7.3	2010	8	1/31	1556	
220	" ", " "	11	8.8	2660	10	1/31	1604	
300	" ", " "	15	1.9	1130	6	2/09	1525	
310	" ", " "	16	3.6	1650	7	2/09	1532	
320	" ", " "	17	5.0	2350	9	2/09	1539	(2)
330	" ", " "	16	4.4	2630	10	2/09	1546	(3)
331	" ", " "	19	5.6	2640	10	2/09	1551	
000	Level Ice, 2 FWD Manifolds	--	--	400	5	1/30	1436	(3)
001	" ", " " "	14	2.0	420	5	1/31	1406	
010	" ", " " "	18	6.9	1760	7	1/31	1416	
020	" ", " " "	13	8.8	2090	9	1/31	1434	
030	" ", " " "	13	10.4	2720	10	1/31	1444	
100	Level Ice, ALL Manifolds	13	3.0	590	5	1/31	1459	
110	" ", " "	11	7.5	1560	7	1/31	1509	
120	" ", " "	16	8.7	2310	9	1/31	1517	
130	" ", " "	20	8.5	2640	10	1/31	1526	
200	" ", " "	14	6.1	2660	10	2/09	1437	
210	" ", " "	13	6.5	2500	9	2/09	1445	(2)
220	" ", " "	14	3.7	1920	7	2/09	--	(3)
221	" ", " "	16	4.7	1750	7	2/09	1459	(2)
230	" ", " "	16	1.3	820	5	2/09	1508	(4)
231	" ", " "	15	1.0	460	5	2/09	1510	(2)
300	" ", " "	26	5.8	2030	8	2/10	1431	
310	" ", " "	27	7.5	2700	10	2/10	1437	

EY FOR COMMENTS:

(1) Speed Measured By Chip Log
(2) In Machinery Report
(3) Aborted
(4) Short Run
(5) Ice Thickness Not Measured
(6) Starboard Manifold Inoperative
(7) Speed Not Measured

TABLE A-2 - BRASH ICE TESTS

TEST NUMBER	TYPE OF TEST	ICE THICKNESS (feet)	APPROX SPEED (knots)	APPROX SHP	CONTROL SETTING	DATE	TIME	COMMENTS
3000	Brash Ice, No Bubbler	-	5.6	220	4	1/31	1839	(5)
3010	" " , " "	-	9.6	760	6	1/31	1849	(5)
3020	" " , " "	-	12.7	2050	8	1/31	1857	(5)
3030	" " , " "	-	13.4	2710	10	1/31	1905	(5)
3100	" " , " "	-	4.6	190	4	2/06	1025	(5)
3110	" " , " "	-	7.5	630	6	2/06	1032	(5)
3120	" " , " "	-	12.8	2020	8	2/06	1039	(5)
3130	" " , " "	-	13.7	2620	10	2/06	1046	(5)
3200	" " , " "	3.5	8.9	2010	8	2/08	1156	
3210	" " , " "	5.0	11.0	2680	10	2/08	1202	
3220	" " , " "	3.5	8.3	1510	7	2/08	1354	
3230	" " , " "	5.0	2.4	410	5	2/08	1441	
3240	" " , " "	4.0	5.0	1140	6	2/08	1447	
3300	" " , " "	3.0	11.8	2680	10	2/08	1325	
3310	" " , " "	5.0	6.6	1210	6	2/08	1331	
3330	" " , " "	4.0	1.8	260	4	2/08	1339	
3400	" " , " "	4.0	10.6	2640	10	2/10	1245	
3410	" " , " "	4.0	7.2	1070	6	2/10	1257	(2)
3420	" " , " "	4.0	0.5	240	4	2/10	1303	(3)
3421	" " , " "	4.0	5.0	580	5	2/10	1306	
3430	" " , " "	4.0	11.4	1890	8	2/10	1333	(2)
3500	" " , " "	4.0	12.1	2520	10	2/10	1250	(2)
3510	" " , " "	4.0	7.6	1170	6	2/10	1312	
3520	" " , " "	4.0	2.7	200	4	2/10	1315	(2)
3530	" " , " "	4.0	11.6	1940	8	2/10	1339	
3600	" " , " "	4.0	2.4	200	4	2/10	1527	
3610	" " , " "	4.0	10.8	1850	8	2/10	1533	
3700	" " , " "	4.0	4.3	-	5	3/13	1216	
3701	" " , " "	4.5	5.0	490	5	3/13	1437	
3710	" " , " "	3.5	8.8	730	6	3/13	1309	
3720	" " , " "	3.0	9.9	1210	7	3/13	1443	
3730	" " , " "	3.5	12.6	1990	8	3/13	1430	
3740	" " , " "	3.5	13.2	2300	9	3/13	1300	
3750	" " , " "	3.5	11.0	2410	10	3/13	1222	

KEY FOR COMMENTS:

(1) Speed Measured By Chip Log
(2) In Machinery Report
(3) Aborted
(4) Short Run
(5) Ice Thickness Not Measured
(6) Starboard Manifold Inoperative
(7) Speed Not Measured

TABLE A-2 - BRASH ICE TESTS (continued)

EST MBER	TYPE OF TEST	ICE THICKNESS (feet)	APPROX SPEED (knots)	APPROX SHP	CONTROL SETTING	DATE	TIME	COMMENTS
000	Brash Ice, FWD Manifolds	1.7	2.7	150	4	2/01	0944	
010	" " , " "	1.7	9.1	750	6	2/01	0952	
020	" " , " "	1.7	12.3	1670	8	2/01	1000	
030	" " , " "	1.7	13.5	2740	10	2/01	1008	
100	Brash Ice, ALL Manifolds	1.7	4.0	180	4	2/01	1017	
110	" " , " "	1.7	9.4	640	6	2/01	1024	
120	" " , " "	1.7	13.2	2020	8	2/01	1032	
130	" " , " "	1.7	13.6	2720	10	2/01	1039	
200	" " , " "	-	3.7	220	4	2/06	0949	(5)
210	" " , " "	-	7.5	610	6	2/06	0957	(5)
220	" " , " "	-	10.6	1710	8	2/06	1005	(4)
221	" " , " "	-	11.5	1970	8	2/06	1009	(5)
230	" " , " "	-	13.1	2580	10	2/06	1016	(5)
300	" " , " "	4.0	12.7	2590	10	2/10	1352	(2)
310	" " , " "	4.0	8.9	800	6	2/10	1401	(2)
320	" " , " "	4.0	3.8	210	4	2/10	1408	
330	" " , " "	4.0	12.2	1720	8	2/10	1425	(2)
400	" " , " "	4.0	12.8	2590	10	2/10	1357	
410	" " , " "	4.0	8.8	790	6	2/10	1412	
420	" " , " "	4.0	2.8	130	4	2/10	1415	(2)
4500	Brash Ice, FWD Manifolds	3.5	6.7	500	5	3/13	1325	
4510	" " , " "	2.3	6.9	610	6	3/13	1503	
4520	" " , " "	4.0	9.0	1150	7	3/13	1239	
4530	" " , " "	3.5	11.5	1840	8	3/13	1319	
4540	" " , " "	3.5	9.9	2230	9	3/13	1245	
4550	" " , " "	4.0	13.0	2480	10	3/13	1450	
4600	Brash Ice, AFT Manifolds	3.5	4.2	550	5	3/13	1339	
4610	" " , " "	3.5	8.8	690	6	3/13	1424	
4620	" " , " "	4.0	10.1	1340	7	3/13	1333	
4630	" " , " "	3.5	11.2	1580	8	3/13	1509	
4640	" " , " "	3.5	12.8	2250	9	3/13	1515	
4650	" " , " "	3.5	13.4	2480	10	3/13	1415	
4700	Brash Ice, ALL Manifolds	3.5	5.4	370	5	3/13	1408	
4710	" " , " "	3.5	7.5	650	6	3/13	1230	(6)
4711	" " , " "	3.5	8.4	850	6	3/13	1356	
4720	" " , " "	3.5	9.6	1230	7	3/13	1522	
4730	" " , " "	3.5	11.8	1770	8	3/13	1350	
4740	" " , " "	3.5	13.1	2260	9	3/13	1528	
4750	" " , " "	3.5	12.8	2500	10	3/13	1402	
4760	" " , " "	3.5	1.3	260	4	3/13	1624	

EY FOR COMMENTS:

(1) Speed Measured By Chip Log
(2) In Machinery Report
(3) Aborted
(4) Short Run
(5) Ice Thickness Not Measured
(6) Starboard Manifold Inoperative
(7) Speed Not Measured

TABLE A-3 - BOLLARD PULL TESTS

TEST NUMBER	TYPE OF TEST	RPM	APPROX BOLLARD PULL	DATE
5000	Ahead Bollard Pull	97	11,000	3/19
5010	" " "	154	23,000	3/19
5020	" " "	211	42,000	3/19
5030	" " "	239	53,000	3/19
5040	" " "	244	54,000	3/19
5050	" " "	245	55,000	3/19
5060	" " "	221	46,000	3/19
5070	" " "	165	26,000	3/19
5080	" " "	128	17,000	3/19
5100	Astern Bollard Pull	100	7,000	3/20
5110	" " "	130	10,000	3/20
5120	" " "	171	17,000	3/20
5130	" " "	222	28,000	3/20
5140	" " "	230	28,500	3/20
5150	" " "	244	32,500	3/20
5160	" " "	254	35,000	3/20

TABLE A-4 - RAMMING TESTS

TEST NUMBER	TYPE OF TEST	ICE THICKNESS (inches)	IMPACT VELOC (knots)	DATE	TIME	COMMENTS
6000	Ramming, No Bubblers	Ridge	-	2/01	1409	(7)
6010	" , " "	Ridge	-	2/01	--	(3)
6020	" , " "	Ridge	-	2/01	1412	(7)
6030	" , " "	Ridge	-	2/01	1420	(7)
6040	" , " "	Ridge	-	2/01	1427	(7)
6100	" , " "	Ridge	-	2/01	1507	(7)
6101	" , " "	Ridge	-	2/01	1524	(7)
6200	Ramming, ALL Manifolds	26	10.8	3/17	1037	
6201	" , " "	26	10.3	3/17	1040	
6202	" , " "	26	9.7	3/17	1044	
6203	" , " "	22	10.0	3/17	1050	
6204	" , " "	27	9.7	3/17	1054	
6205	" , " "	24	9.7	3/17	1058	
6301	Ramming, AFT Manifolds	30	9.7	3/17	1101	
6302	" , " "	31	8.1	3/17	1105	
6303	" , " "	30	9.2	3/17	1108	
6304	" , " "	26	9.7	3/17	1111	
6305	" , " "	27	10.3	3/17	1115	
6400	Ramming, FWD Manifolds	24	9.7	3/17	1118	
6401	" , " "	26	9.7	3/17	1128	
6402	" , " "	24	8.6	3/17	1132	
6403	" , " "	26	9.4	3/17	1135	
6404	" , " "	31	8.6	3/17	1138	
6405	" , " "	22	-	3/17	1142	(7)
6500	Ramming, No Bubblers	26	8.1	3/17	1252	(2)
6501	" , " "	33	10.0	3/17	1256	
6502	" , " "	26	9.2	3/17	1258	
6503	" , " "	26	8.9	3/17	1302	
6504	" , " "	29	8.6	3/17	1305	
6610	" , " "	35	11.9	3/17	1307	
6611	" , " "	27	12.1	3/17	1312	
6612	" , " "	23	13.2	3/17	1322	(2)
6620	Ramming, ALL Manifolds	24	12.6	3/17	1328	
6621	" , " "	29	13.4	3/17	1333	
6622	" , " "	26	13.3	3/17	1340	
6630	Ramming, AFT Manifolds	27	13.6	3/17	1346	
6631	" , " "	25	13.2	3/17	1348	
6632	" , " "	28	13.0	3/17	1360	
6640	Ramming, FWD Manifolds	28	13.2	3/17	1406	
6641	" , " "	32	13.1	3/17	1411	
6642	" , " "	32	12.6	3/17	1415	

KEY FOR COMMENTS:

(1) Speed Measured By Chip Log
(2) In Machinery Report
(3) Aborted
(4) Short Run
(5) Ice Thickness Not Measured
(6) Starboard Manifold Inoperative
(7) Speed Not Measured

TABLE A-5 - COMPARISON AND MANEUVERING TESTS

TEST NUMBER	TYPE OF TEST	DATE	SPEED	TIME	COMMENTS
7000	Comparison Test Between 140' WTGB and 110' WYTM	2/09	MAX	1049	Photographic Documentation Only
8000	Level Ice Maneuvering	2/09	MAX	1635	Right Full Rudder
8100	Level Ice Maneuvering	2/09	MAX	1646	Left Full Rudder
9600	Brash Ice Maneuvering	3/17	MAX	1458	Left Full Rudder
9700	Brash Ice Maneuvering	3/17	MAX	1505	Right Full Rudder

TABLE A-6 - SHAFT/PROPELLER VALIDATION TESTS

TEST NUMBER	TYPE OF TEST			RPM	TURN	DATE	TIME	COMMENTS
0010	Shaft	Vibrations		151	NO	2/13	1418	
0020	"	"		162	NO	2/13	1423	
0030	"	"		168	NO	2/13	1432	
0040	"	"		180	NO	2/13	1439	
0050	"	"		189	NO	2/13	1449	
0060	"	"		200	NO	2/13	1456	
0070	"	"		211	NO	2/13	1505	
0080	"	"		221	NO	2/13	1512	
0090	"	"		228	NO	2/13	1521	
0100	"	"		242	NO	2/13	1527	
0110	"	"		247	NO	2/13	1536	
0120	"	"		261	NO	2/13	1543	
0130	"	"		270	NO	2/13	1602	
0140	"	"		284	NO	2/13	1612	
0150	"	"		291	NO	2/13	1619	
0151	"	"		291	NO	2/13	1624	
0160	"	"		301	NO	2/13	1628	
0170	"	"	Turning	305	Left	2/13	1638	35° Rudder Used
0180	"	"	"	305	Right	2/13	1640	35° Rudder Used
0190	"	"	"	305	Left	2/13	1642	35° Rudder Used
0200	"	"	"	305	Right	2/13	1645	35° Rudder Used

TABLE A-7 - RUDDER TORQUE TESTS

TEST NUMBER	TYPE OF TEST	TURN	APPROX SPEED (knots)	RPM	DATE	TIME
12000	Rudder Torque Ahead	Left	12	215	2/13	1659
12010	" " "	Right	12	215	2/13	1701
12020	" " "	Left	9	165	2/13	1703
12030	" " "	Right	9	165	2/13	1705
12040	" " "	Left	6	110	2/13	1708
12050	" " "	Right	6	110	2/13	1710
12060	" " "	Left	3	55	2/13	1714
12070	" " "	Right	3	55	2/13	1716
12080	Rudder Torque Astern	Left	5	100	2/13	1721
12090	" " "	Right	5	100	2/13	1723
12100	" " "	Left	10	200	2/13	1726
12110	" " "	Right	10	200	2/13	1728

TABLE A-8 - SPIRAL TESTS

TEST NUMBER	TYPE OF TEST	APPROX SPEED (knots)	RPM	DATE	COMMENTS
3000	Ahead Spiral 15°R to 15°L to 15°R Rudder	5	78	7/10	Very stable
3100	Ahead Spiral 15°R to 15°L to 15°R Rudder	10	165	7/09	Very stable
3200	Astern Spiral 15°R to 15°L to 30°R Rudder	10	165	7/10	Unstable
3300	Astern Spiral 15°R to 30°L, 30°R Rudder	5	81	7/10	No Control Ship backs into the wind

CONDITIONS

7/9/79	Depth of Water	200 feet
	Drafts	11'0" FWD 12'6" AFT
	Wind	4-8 knots
	Current	0 knots
	Wave Height	Less than 1 foot
7/10/79	Depth of Water	200 feet
	Drafts	11'0" FWD 12'6" AFT
	Wind	6-8 knots
	Current	0 knots
	Wave Height	Less than 1 foot

TABLE A-9 - SPEED VERSUS RPM TESTS

TEST NUMBER	TYPE OF TEST	RPM	APPROX SPEED (knots)	DATE	TIME	REL WIND DIRECT	REL WIND SPEED (knots)
101	Speed Versus RPM	40.5	2.5	7/09	1042	S	4
102	" " "	42.2	2.5	7/09	1118	H	14
104	" " "	80.7	5.1	7/09	1050	S	2
105	" " "	80.0	5.1	7/09	1111	H	16
107	" " "	120.4	7.6	7/09	1058	S	0
108	" " "	120.4	7.5	7/09	1106	H	15
110	" " "	162.5	9.9	7/09	1127	S	0
111	" " "	162.9	9.9	7/09	1138	H	20
113	" " "	200.7	11.4	7/09	1223	S	0
114	" " "	201.3	11.4	7/09	1233	H	22
116	" " "	241.1	13.1	7/09	1243	H	2
117	" " "	241.5	13.1	7/09	1250	H	25
119	" " "	283.4	14.4	7/09	1305	H	2
120	" " "	283.6	14.2	7/09	1311	H	27
122	" " "	303.9	14.7	7/09	1318	H	3
123	" " "	303.4	14.7	7/09	1325	H	25

H = Wind from Ahead
S = Wind from Astern

Current Speed	Approx 0
Water Depth	180'
Water Temperature	57^{o}
Drafts	11'0" FWD
	12'6" AFT

TABLE A-10 - TACTICAL TRIALS

EST MBER	TYPE OF TEST	APPROX SPEED (knots)	RUDDER ANGLE	DATE	TIME	WIND SPEED	COMMENTS
201	Turning Circle	5.0	10^{o}R	7/10	1310	6	
202	" "	5.0	20^{o}R	7/10	1330	6	
203	" "	5.0	30^{o}R	7/10	1345	6	
204	" "	5.0	10^{o}L	7/10	1417	4	
205	" "	5.0	20^{o}L	7/10	1444	6	
206	" "	5.0	30^{o}L	7/10	1457	6	
207	" "	10.0	10^{o}L	7/10	1512	6	
208	" "	10.0	20^{o}R	7/10	1600	6	
209	" "	10.0	30^{o}R	7/10	1612	6	
210	" "	10.0	10^{o}R	7/10	1550	6	
211	" "	10.0	20^{o}L	7/10	1526	6	
212	" "	10.0	30^{o}L	7/10	1537	6	
213	" "	14.7	10^{o}R	7/10	1705	6	
214	" "	14.7	20^{o}R	7/10	1730	6	
215	" "	14.7	30^{o}R	7/10	1742	6	
216	" "	14.7	10^{o}L	7/10	1754	6	
217	" "	14.7	20^{o}L	7/10	1807	6	
218	" "	14.7	30^{o}L	7/10	1812	6	
301	Crash Stop	5.0		7/10	1357	6	
302	" "	7.5		7/10	1404	6	
303	" "	10.0		7/10	1411	6	
304	" "	12.5		7/10	1620	6	
401	Full Ahead To Full Astern	14.7		7/10	1635	6	Terminated Early
402	Full Astern To Full Ahead	-		7/10	1637	6	
403	Full Ahead To Full Astern	14.7		7/10	1645	6	Terminated Early
501	Bubbler Effect in Open Water	0		7/09	1338	9	All Bubbler Manifolds
502	Bubbler Effect in Open Water	0		7/09	1344	9	All Bubbler Manifolds

TABLE A-11 - BUBBLER SYSTEM PERFORMANCE

DATE	BLOWER RPM	MANIFOLD PRESSURE psig	TOTAL CFM	MANIFOLD ARRANGEMENT	HP FROM BLOWER CURVES	HP CORRECTED TO 14°F INLET
1/31	1600	6.5-7.0	7250	ALL	260	280
1/31	1050	9.0-9.5	4300	FWD	240	260
2/01	1600	6.0	8000	ALL	240	260
2/01	1150	9.5	4500	FWD	260	280
2/06	1650	6.0	8000	ALL	240	260
3/13	1600	6.0-6.5	8000	ALL	240	260
3/13	1000	8.9-9.0	3920	FWD	220	240
3/13	1600	7.5-7.9	6000	AFT	290	315

TABLE A-12 - SPIRAL TEST DATA

)ate: 10 July 1979
)rafts: 11'0" FWD
12'6" AFT

USCGC KATMAI BAY
Wave Height: Less than 6 inches
Wind Speed: 6 knots
Wind Direction: 110°T

Jater Depth: 200 feet

'est Location: South side of Whitefish Bay, Lake Superior

ihaft RPM: 165 RPM Astern Speed: Approximately 10 knots

RUDDER ANGLE	YAW RATE DEG/SEC	HEADING RANGE °T
15R	1.35L	350-110
10R	1.41L	080-310
4.5R	1.00L	280-160
3R	1.18L	140-040
1R	1.01L	025-250
0	0.71L	240-160
1L	Left-Right	150-130
3L	1.64R	130-330
5L	1.62R	030-190
10L	1.72R	210-030
15L	1.83R	080-260
10L	1.65R	300-150
5L	1.59R	190-340
3L	1.56R	000-170
1L	1.54R	190-330
0	1.46R	000-150
1R	1.47R	165-310
3R	1.42R	350-130
5R	1.42R	145-290
10R	1.29R	325-090
15R	1.24R	120-250
20R	1.26R	280-045
25R	1.32R	080-210
30R	1.36R	230-010

rror: ±1/2 deg. ±0.07

TABLE A-13 - SPIRAL TEST DATA

Date: 9 July 1979
Drafts: 11'0" FWD
12'6" AFT

USCGC KATMAI BAY
Wave Height: Less than 1 foot
Wind Speed: 8 knots
Wind Direction: 080°T

Water Depth: 200 feet

Test Location: South side of Whitefish Bay, Lake Superior

Shaft RPM: 165 RPM Ahead   Speed: Approximately 10 knots

RUDDER ANGLE	YAW RATE DEG/SEC	HEADING RANGE °T
15R	1.94R	
10R	1.42R	
5R	1.01R	
3R	0.63R	200-250
1R	0.33R	270-310
0	0	320-320
1L	0.22L	320-290
3L	0.53L	280-240
5L	0.76L	220-180
10L	1.40L	150-080
15L	1.91L	030-310
10L	1.18L	260-150
5L	0.73L	120-090
3L	0.55L	070-020
1L	0.22L	010-350
0	0.16R	350-355
1R	0.30R	000-030
3R	0.66R	
5R	1.04R	
10R	1.57R	
15R	1.92R	340-080

Error: $\pm 1/2$ deg. ± 0.05

TABLE A-14 - SPIRAL TEST DATA

ıate: 10 July 1979
ırafts: 11'0" FWD
12'6" AFT

USCGC KATMAI BAY
Wave Height: Less than 1 foot
Wind Speed: 8 knots
Wind Direction: 110°T

'ater Depth: 200 feet

'est Location: South side of Whitefish Bay, Lake Superior

·haft RPM: 78 RPM Ahead Speed: Approximately 5 knots

RUDDER ANGLE	YAW RATE DEG/SEC	HEADING RANGE °T
15R	1.00R	240-350
10R	0.67R	020-090
4R	0.38R	100-140
3R	0.27R	150-180
1R	0.06R	185-195
0	0.06L	195-190
1L	0.12L	190-170
3L	0.24L	165-150
5L	0.36L	140-100
10L	0.73L	090-330
15L	0.98L	315-200
10L	0.58L	190-120
5L	0.36L	110-065
3L	0.21L	060-025
1L	0	025-025
0	0.08R	025-035
1R	0.15R	035-050
3R	0.33R	050-100
5R	0.57R	105-160
10R	0.75R	170-260
15R	0.98R	290-030

rror: ±1/2 deg. ±0.05

TABLE A-15 - SPIRAL TEST DATA

Date: 10 July 1979
Drafts: 11'0" FWD
12'6" AFT

USCGC KATMAI BAY
Wave Height: Less than 1 foot
Wind Speed: 8 knots
Wind Direction: 110°T

Water Depth: 200 feet

Test Location: South side of Whitefish Bay, Lake Superior

Shaft RPM: 81 RPM Astern   Speed: Approximately 5 knots

RUDDER ANGLE	YAW RATE DEG/SEC	HEADING RANGE °T
15R	0.55R	210-260
10R	0.64R	290-350
5R	0.71L	355-320
3R	0.61L	310-250
1R	0.75R	245-290
0	0.75R	300-020
1L	0.23R	030-060
3L	0.61L	060-350
5L	0.54L	340-270
10L	0.91R	260-330
15L	0.88R	340-080
30L	0.93R	100-240
30R	0.70R	280-350

Ship did not respond to rudder (unstable), backs into wind

DATE
ILME